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A CRASHWORTHY ARMORED PILOT SEAT FOR HELICOPTERS

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Naval Air Development Center

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18 January 1974

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The accelerations which can occur duing crashes of rotary- and light fixed-wing aircraft have been shown to be injurious or fatal to human occupants. Under a joint Army and Navy program, ARA, Inc. developed a crash survivable seat using Government Furnished Equipment in the form of an armored bucket, restraint system, and cushions. The seat system was designed to meet as many of the requirements of MIL-S-58095 (AV) within the physical limitations of existing space requirements in present helicopters.

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20. Based on a maximum of 8 inches of vertical stroke when the seat is in the lowest position, the seat pan accelerations were within the tolerable decelerations for the 95th percentile crash, that is, a 50 feet per second crash velocity with a triangular deceleration pulse of 48 g's.

The weight penalty of the crash survivable armored seat compared to the existing seat in the UH-1 helicopter, which is limited to crash decelerations of 8 g's, is 7 1/2 pounds. By modification of the present GFE cushion and restraint system in the UH-1, this weight penalty could be reduced so that the weight penalty due to crash survivability is negligible.

In addition to meeting the crash worthiness requirements of MIL-S-58095(AV), all of the required environmental tests were also concluded. The results of all the environmental tests, which the seat successfully met, are summarized in this report.

FOREWORD

The work described in this report, although performed by ARA, Inc. under contract to the U. S. Navy, also included the important contributions of the U. S. Army Aviation Systems Command and U. S. Navy/Naval Air Development Center personnel. In particular, Mr. Daniel Sabo was the AVSCOM Project Engineer who directed the overall effort of the program and was instrumental in solving many of the interface problems of the crashsurvivable seat with the aircraft. Mr. Marvin Schulman of the U. S. Navy/NADC, was not only the principal technical director of the program, but conducted all the dynamic tests at the NADC sled and drop tower facility. Numerous other personnel at ARA, Inc., AVSCOM, and NADC, contributed measurably to this program. Their efforts are appreciated.

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I SUMMARY

The accelerations which can occur during crashes of rotary- and light fixed-wing aircraft have been shown to be injurious or fatal to human occupants. Under a joint Army and Navy program, ARA, Inc. developed a crash survivable seat using Government Furnished Equipment in the form of an armored bucket, restraint system, and cushions. The seat system was designed to meet as many of the requirements of MIL-S-58095 (AV) within the physical limitations of existing space requirements in present helicopters. Based on a maximum of 8 inches of vertical stroke when the seat is in the lowest position, the seat pan accelerations were within the tolerable decelerations for the 95th percentile crash, that is, a 50 feet per second crash velocity with a triangular deceleration pulse of 48 g's.

The weight penalty of the crashsurvivable armored seat compared to the existing seat in the UH-1 helicopter, which is limited to crash decelerations of 8 g's, is 7-1/2 pounds. By modification of the present GFE cushion and restraint system in the UH-1, this weight penalty could be reduced so that the weight penalty due to crashsurvivability is negligible.

In addition to meeting the crashworthiness requirements of MIL-S-58095(AV), all of the required environmental tests were also concluded. The results of all the environmental tests, which the seat successfully met, are summarized in this report.

I. INTRODUCTION

The impact forces due to decelerations which occur during a potentially survivable crash of rotary and light-fixed-wing military aircraft have often been found to be injurious or fatal to flying personnel. The Army, Navy and Air Force have been seeking an attenuation system which will limit those impact forces to human tolerance levels and increase the chance of crash survivability. There are cases where some seats in military light aircraft and helicopters have failed in accidents in which the integrity of the fuselage structure which surrounds occupants was maintained. In order to alleviate the forces transmitted to occupants during a crash, a shock attenuating seat-occupant system is considered to be necessary.

The Army has studied previous crashes and consolidated the design criteria of aircraft structural crashworthiness and occupant acceleration environment into the Crash Survival Design Guide [1]. Information presented in this design guide will be used throughout this report. From collected crash data, the ninety-fifth percentile (95th%) crash load was determined. The crash pulse was found to be closely approximated by a triangular pulse. The human injury level is in general well below the peak loads sustained during a crash. The ability to reduce the crash load to the human tolerance level with minimum structural weight, cost and long term reliability are all factors considered important by the Army in their design guide.

The present report is a summary of the work done under Contract N62269-72-C-0657 in developing an armored energy attenuating crewmen seat for fixed seat aircraft. The description of the bucket and frame support system is given in Section II. A two-dimensional mathematical model for developing the design and mathematical analysis of the seating system was developed.

The analytical results of the dynamic response to various impact conditions are described in Section III. The loads obtained from the dynamic analysis were used to evaluate the stress and size of the frame members. This stress analysis is presented in Section IV. The next two sections, namely V and VI describe, respectively, the results of the developmental dynamic tests and the environmental tests of the seat system. Upon completion of ARA's test program, prototype units were delivered to NADC for evaluation. These prototype units incorporated all structural changes required by the ARA test program. Section VII describes the results of the NADC acceptance test.

III. GENERAL DESCRIPTION OF SEATING SYSTEM

The assembled configuration of the armored seat and supporting frame structure is shown in Figures 1 through 3 and the engineering top assembly drawing is given in Figure 4, ARA Drawing D-2387. The armored bucket is attached to the upright frame through a system of six (6) energy absorbers. The energy absorbers (E/A) are ARA's velocity insensitive TOR-SHOKs which have unique square wave load-deflection characteristics. During an impact, the stroking E/A's attenuate the accelerations experienced by the pilot. The degree of attenuation is determined by the combined mass of the seat bucket and pilot, and the preset loads in the E/A's. The final E/A loads in the seating system were determined by the dynamic analysis and a series of dynamic tests.

The purpose of using a shock attenuating seat frame is to limit the maximum G load experienced by the pilot to within the human maximum allowable level. In the dynamic analysis, the pilot and the bucket are treated as a single rigid body and this combined body sustains about half the G load of the input peak

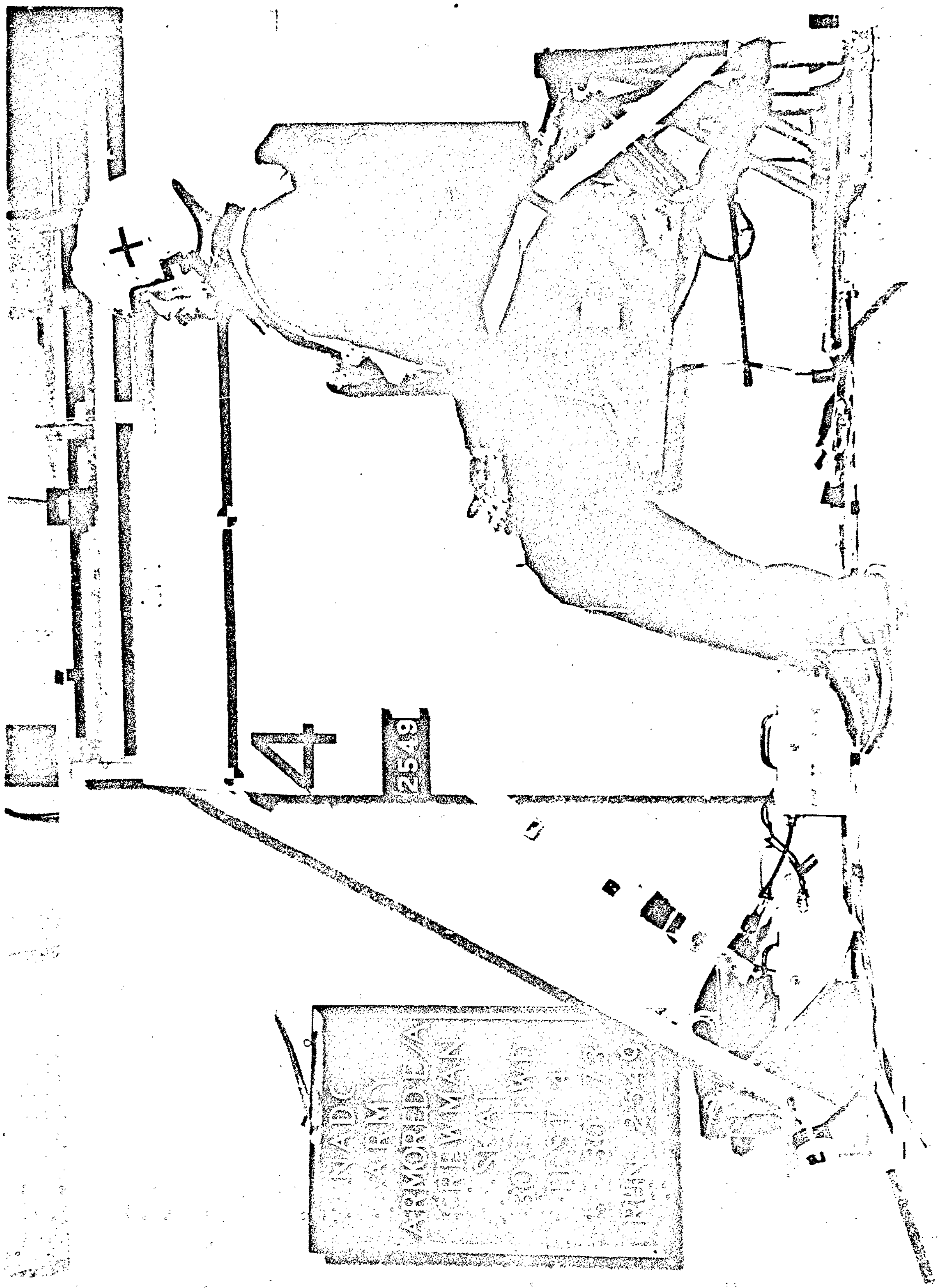


Figure 1. Seat Side View

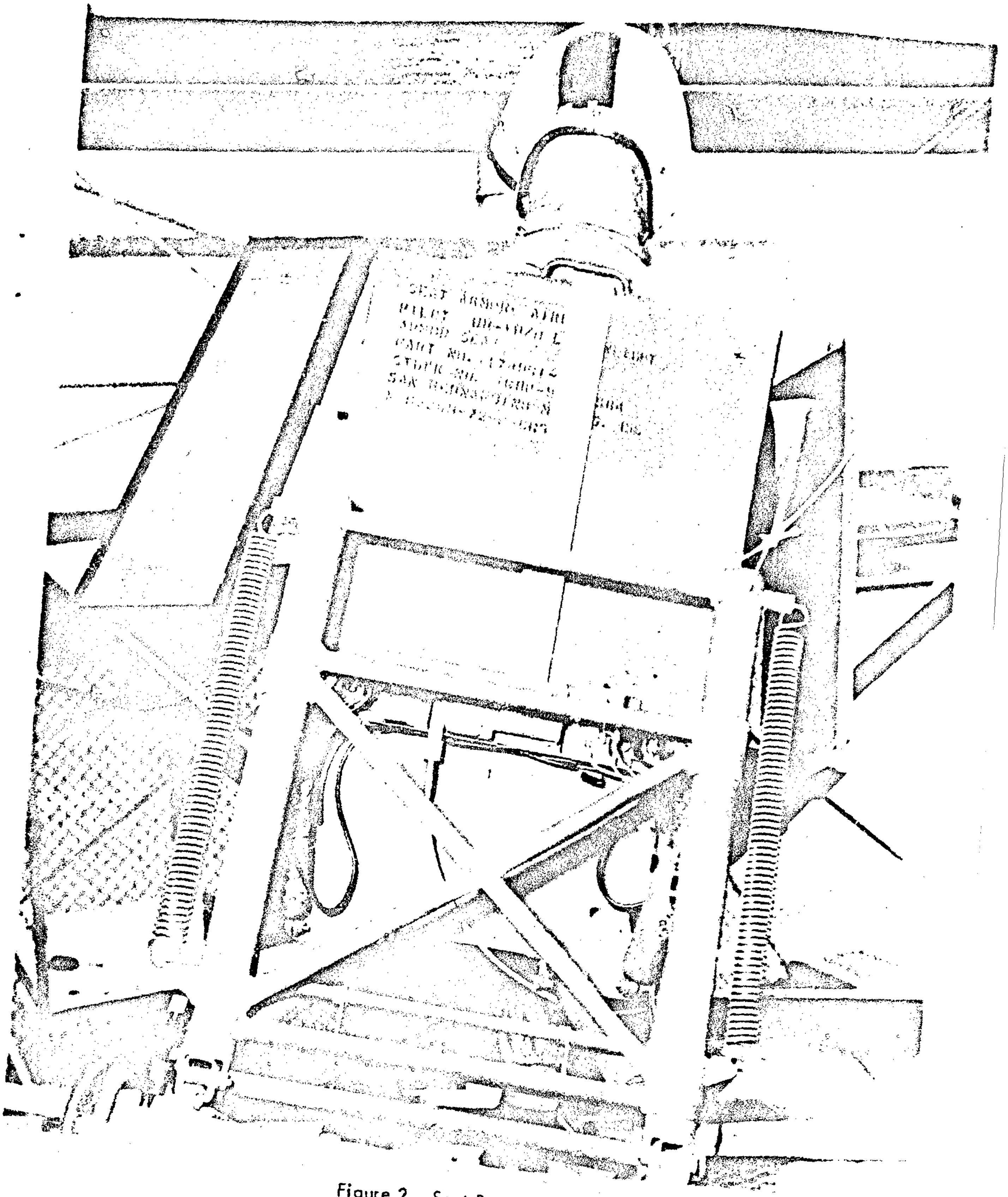


Figure 2. Seat Rear View

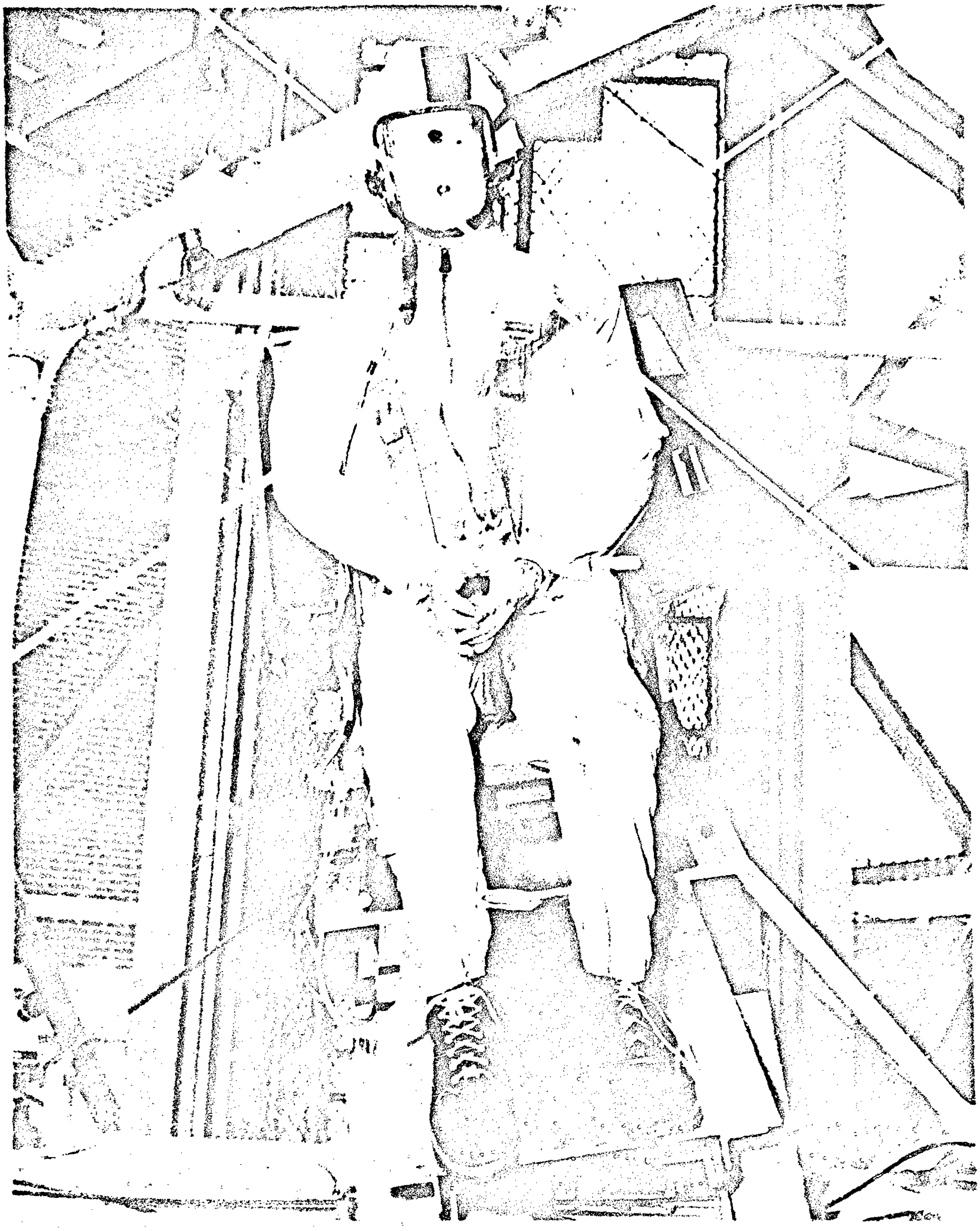
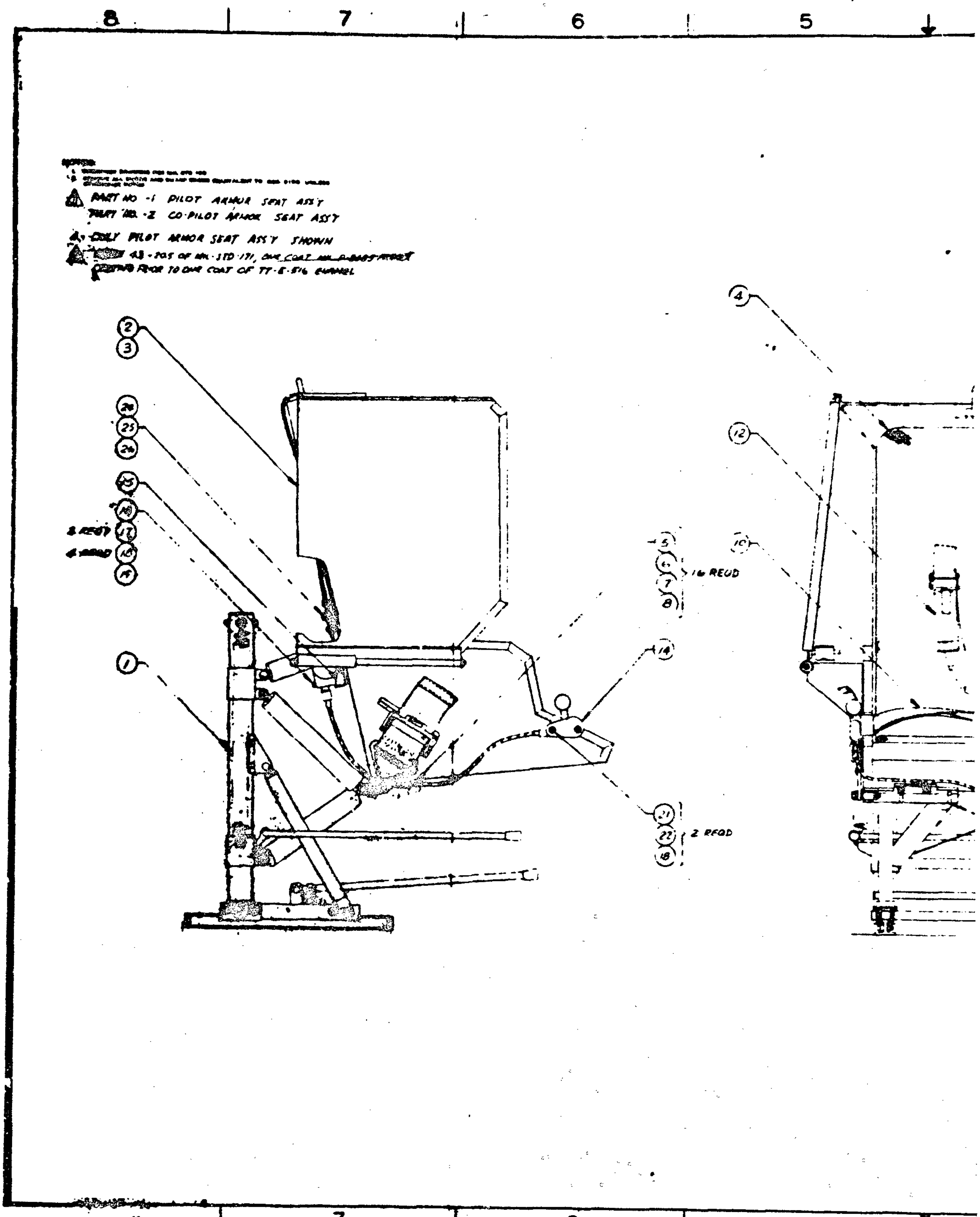


Figure 3. Seat Front View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5
PART NO -1 PILOT ARMOR SEAT ASS'Y
PART NO. -2 CO-PILOT ARMOR SEAT ASS'Y
ONLY PILOT ARMOR SEAT ASS'Y SHOWN
43-205 OF MIL-STD-171, ONE COAT
PRIOR TO ONE COAT OF TT-E-516 ENAMEL
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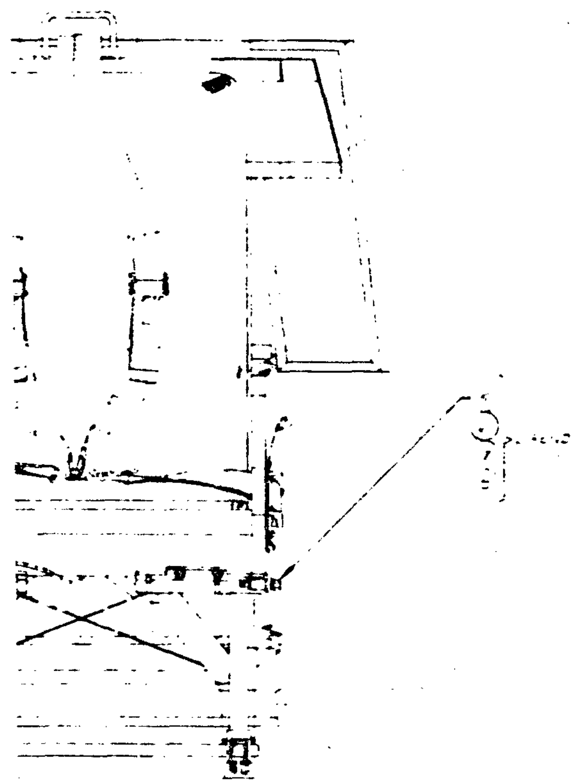

		MATERIAL/SPECIFICATION	
	ENAMEL, LUSTERLESS	[illegible] DRAB, COLOR [illegible] FED-STD-595 / TT-E-516	
	[illegible] COATING	ZINC CHROMATE, MIL-P-8585 [illegible]	
			27
MS[illegible]	NUT, HEX	[illegible]	
MS[illegible]	WASHER, LOCK	[illegible]	
MS[illegible]	SCREW, [illegible]	[illegible]	
MS35[illegible]	NUT, HEX	#10-32	
MS[illegible]	SCREW, [illegible] HEAD	#10-32 × [illegible]	
MS[illegible]	SCREW, [illegible] HEAD	#10-32 × [illegible]	
MS[illegible]	WASHER, LOCK	#10	
AN3-3A	BOLT, MACHINE	#10-32 × [illegible]	17
AN3-[illegible]A	BOLT, MACHINE	#10-32 × [illegible]	16
2351	BRACKET, REEL		15
[illegible]	HARNESS REEL ASSY	MIL-R-8236C	14
			13
2383	SHOULDER HARNESS		12
			11
2386	LAP BELT		10
			9
AN960-[illegible]	WASHER, FLAT	5/16 × .063	8
MS35338-[illegible]	WASHER, LOCK	5/16	7
MS[illegible]	NUT, HEX	5/16-18	6
MS90726-[illegible]	SCR, HEX HEAD	5/16-18 × [illegible]	5
[illegible]	BUCKET ASSY		4
780[illegible]	SHELL, [illegible] PILOT		3
[illegible]	SHELL, SEAT, PILOT		2
2269	SUPPORT STRUCTURE		1

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ARMOR SEAT ASSEMBLY, UH 1 HELICOPTER

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G in the triangular pulse in the vertical impact. The 5th and 95th percentile pilot were used in the dynamic analysis and the 95th percentile pilot was used in the dynamic tests. Since the human body can tolerate higher G loads in the horizontal direction than in the vertical direction, and the aircraft crash data shows that a greater peak G impulse exists in the vertical direction, the present seating system is primarily designed such that the energy absorbers bring the seat to rest in a controlled attenuation rate in the case of the most severe vertical impact. Reference 1 shows that the impact G load in horizontal crashes is within human tolerance. Therefore, the attenuation system in the horizontal direction is designed to minimize the structural weight of the frame system. The dynamic analysis for the horizontal impact case allows for this optimization while the horizontal sled test substantiates the structural integrity of the seat system.

The weight of the seat frame, including the E/A's is approximately 30 pounds, which is a decrease of 25 pounds over the previous energy-attenuating seat designed by ARA, Inc. [2]. The decrease in weight is attributed to re-arranging the E/A's and modifying the back frame. The two main vertical tubes which represent the major structural members have been reduced in height from 35-1/2" to 20". The new design is much more compact and stiffer than the previous one, and yet, is only 7-1/2 pounds heavier than the non-energy-absorbing frame used in current fixed seat aircraft. The seating system is placed on rails with 16-inch centers, which is compatible with most current fixed seat aircraft.

The adapter brackets for current fixed seat aircraft armored ceramic buckets have been designed. Using the existing hole pattern, they are used to mount necessary clevises and hardware for attaching the inertia reel, seat belt and E/A members. In the event that a new bucket is fabricated, the hole pattern

in the bucket should be modified to eliminate the use of these adapter brackets.

The range of vertical and horizontal seat adjustments which meet the requirements of Military Standards MIL-STD-1333 and MIL-S-58095 (AV) is shown in Figure 5. The 4-way seat adjustment is for the 5th through 95th percentile pilot population and provides a 5-inch vertical adjustment and a 3-inch fore-and-aft adjustment in increments of 1/2 inch.

IV. DYNAMIC ANALYSIS

The three most important degrees of freedom in defining the motion of the crewmen seat during a symmetric crash are pitching, forward and vertical movements. They constitute the main limiting factors in determining the E/A stroking forces. The computer code to analyse this three-dimensional dynamic response of the seat and pilot has been developed previously by ARA, Inc. under Navy Contract N00156-71-C-0890. The geometry and loading conditions were assumed to be symmetric with respect to a plane passing through the seat's CG and fore-and-aft axis. This computer program was used to calculate the initial value for the E/A stroking forces and to locate the optimum E/A positions for the present seating system. The detailed formulation of this two-dimensional crewman-seat model is given in Reference 3. The following assumptions are made in the mathematical model:

(1) The pilot and bucket are treated as a single rigid body.

(2) Elastic deformation of the seat frame is small and negligible when compared to the E/A's stroking distance.

(3) The pilot and the seat system are symmetric with respect to the vertical plane passing through the seat's CG and the fore-and-aft axis.

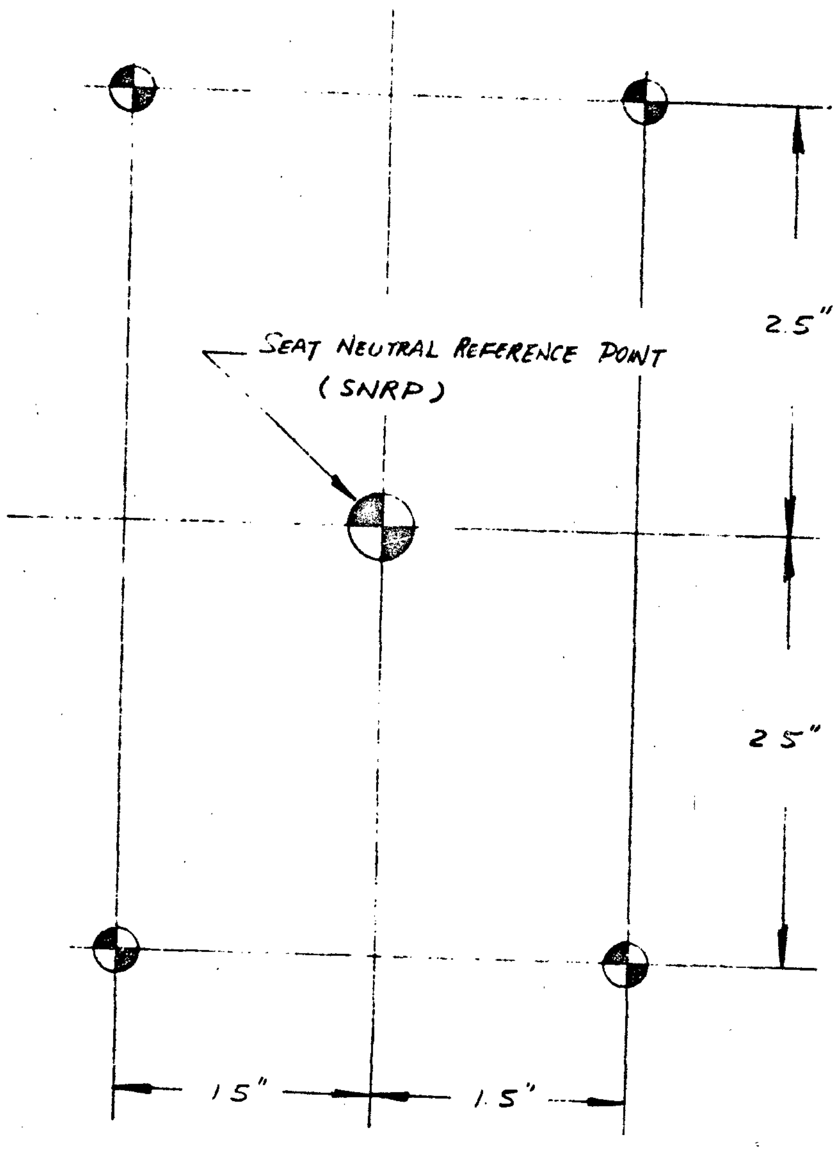


Figure 5. 4-Way Seat Adjustment.

The factors which effect the final design of the energy absorbing system include the input pulse, the effective occupant weight, the weight of the movable part of the seat, the characteristics of the seat cushion, and the available stroke distance. A typical impact pulse used in the dynamic analysis is shown in Figure 6. The vertical, horizontal, and oblique impact decelerations with magnitudes as suggested in Reference 1 were performed in the computer simulation when the seat was at the uppermost position. Table 1 summarizes the analytical results obtained for the displacement and resulting G load experienced by the combined pilot-seat mass for three design impact pulses. The 95th percentile pilot was used to establish the worst impact condition imposed on the seating system. The pilot-seat weight configuration is summarized in Table II. It should be noted that the effective weight of a seated occupant as suggested in Reference 1 has been used in computing the responses for the vertical impact.

During the study of the motion of the seat, several dynamic characteristics pertinent to the design of the E/A's were observed for all loading conditions. The bottom E/A was often in compression during the impact. In order to limit the amount of seat pitching and to maintain a minimum clearance between the seat bottom and the supporting frame structure, the bottom E/A was allowed to stroke in tension only. For the case of vertical impacts, the middle E/A dominates the energy absorbing capability of the system. It was found that the final vertical displacement of the seat varied approximately linear to the force setting of the middle E/A. If the allowable vertical displacement is known, the force setting of the E/A can be easily determined. For the present design, the available maximum vertical stroke distance is approximately 8 to 8.5 inches. For the horizontal impact, it was observed that the top E/A plays the most important role in minimizing the pitching response of the seat. The force setting of this

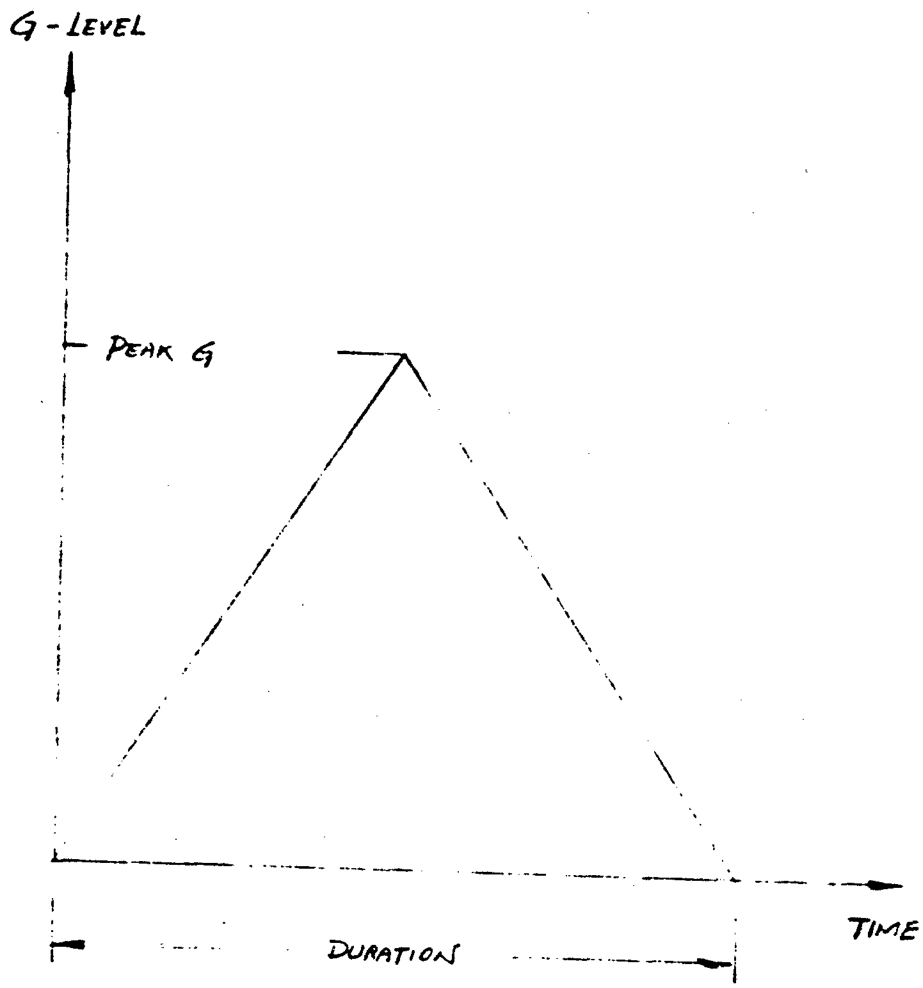


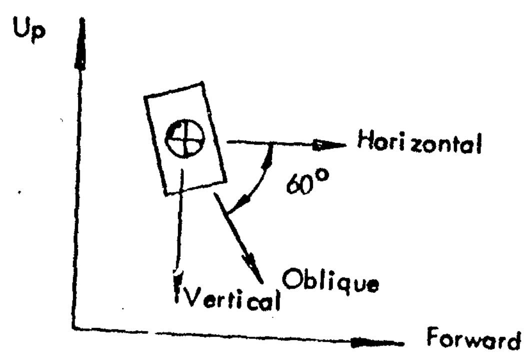
Figure 6. Typical Impact Pulse

Table 1. Summary of Seat-Pilot Dynamic Response for 5th and 95th Percentile Pilots

Impact	Peak Input G	Seat-Pilot Response											
		Peak G				Displacement							
		Horizontal		Vertical		Forward (inches)		Downward (inches)		Pitch** (degs. clockwise)			
		95th	5th	95th	5th	95th	5th	95th	5th	95th	5th		
Horizontal	30	23.1	25.0	3.7	2.9	5.3	2.4	3.6	1.3	18.0	8.3		
Vertical	48	8.7	9.0	18.1	21.9	-0.9	-1.1	8.5	5.9	-3.8	-7.6		
Oblique*	48	17.9	18.8	21.7	22.0	2.2	2.2	8.0	7.0	3.2	3.2		

* Seat displacements are limited by top E/A's stroking to its maximum allowable length.

** Initial pitch angle of bottom surface of bucket relative to floor is -6.0°.



Direction of Impact

Table II. Pilot-Seat Weight Configuration

Pilot Weight Percentile	95th	5th
Weight of Pilot & Equipment, lbs.	211	146
Weight of Bucket, lbs.	127	127
Total Weight, lbs.	338	273
Rotational Inertia, lb. (mass)-in^2	232	199
Effective Weight, lbs.	293	241
Effective Inertia, lb. (mass)-in^2	209	183

E/A was so chosen such that the maximum angular pitch angle of the seat was limited to 18 degrees.

The geometry of the final seat configuration with E/A's is shown in Figure 7. The force setting of E/A's and the stroking responses due to three design impact pulses are given in Table III. The attenuated G load experienced by the pilot-seat single rigid body with the 5th and 95th percentile pilots for different impacts are shown in Figures 8 through 10. The final displacements of the seat for the 95th percentile pilot are shown in Figures 11 through 13. For a vertical crash pulse, Figure 8 shows that the 95th percentile clothed pilot experiences an average deceleration of 16-1/2 G and the 5th percentile clothed occupant experiences approximately a 20 G average deceleration. Thus, the present seating system meets the requirement of Section 6.3.9 of MIL-S-58095 (AV) for the 5th through 95th percentile occupants. Figure 14 combines the average responses of the present analysis with that of Figure 12 in MIL-S-58095 (AV). This figure clearly shows that the occupants do not experience acceleration with plateaus lasting longer and/or greater in magnitude than the values represented by the maximum acceptable acceleration duration-magnitude curve given in Figure 12 of MIL-S-58095 (AV). If a boron carbide bucket had been used in this analysis such that the bucket weight would have been reduced by 25 pounds, then the difference between the 5th and 95th percentile vertical responses would have been larger. On that basis, the 5th percentile would have exceeded the tolerance level of MIL-S-58095 (AV). In order to reduce the response for the 5th percentile, then a larger stroke would be required for the 95th percentile, requiring a hole in the floor. Thus, the optimum seat is not necessarily the one with the lightest bucket from the standpoint of either stroking requirements or cost.

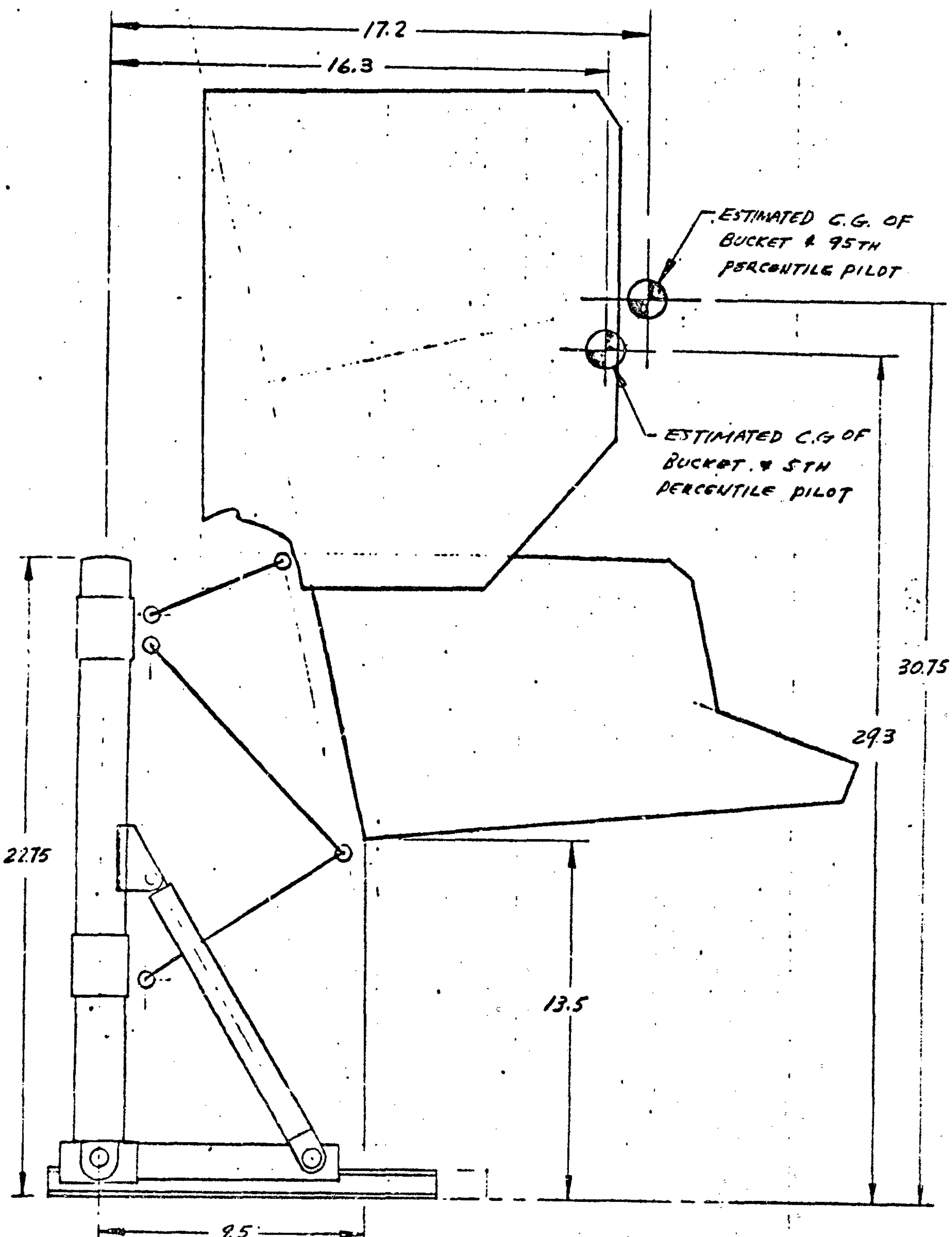


Figure 7. General Layout, Highest Seat Position.

Table III. Response of E/A members.

TOK-SHOK Energy Absorber		Top		Middle		Bottom	
Preset Force, lbs.		3000		1380		2100	
Stroke, in	Pilot Percentile	95th	5th	95th	5th	95th	5th
	Vertical Impact	3.0	1.8	7.8	6.1	0	0
	Horizontal Impact	3.0	1.4	0	0	0	0
	Oblique Impact	3.0	3.0	6.4	5.5	0	0

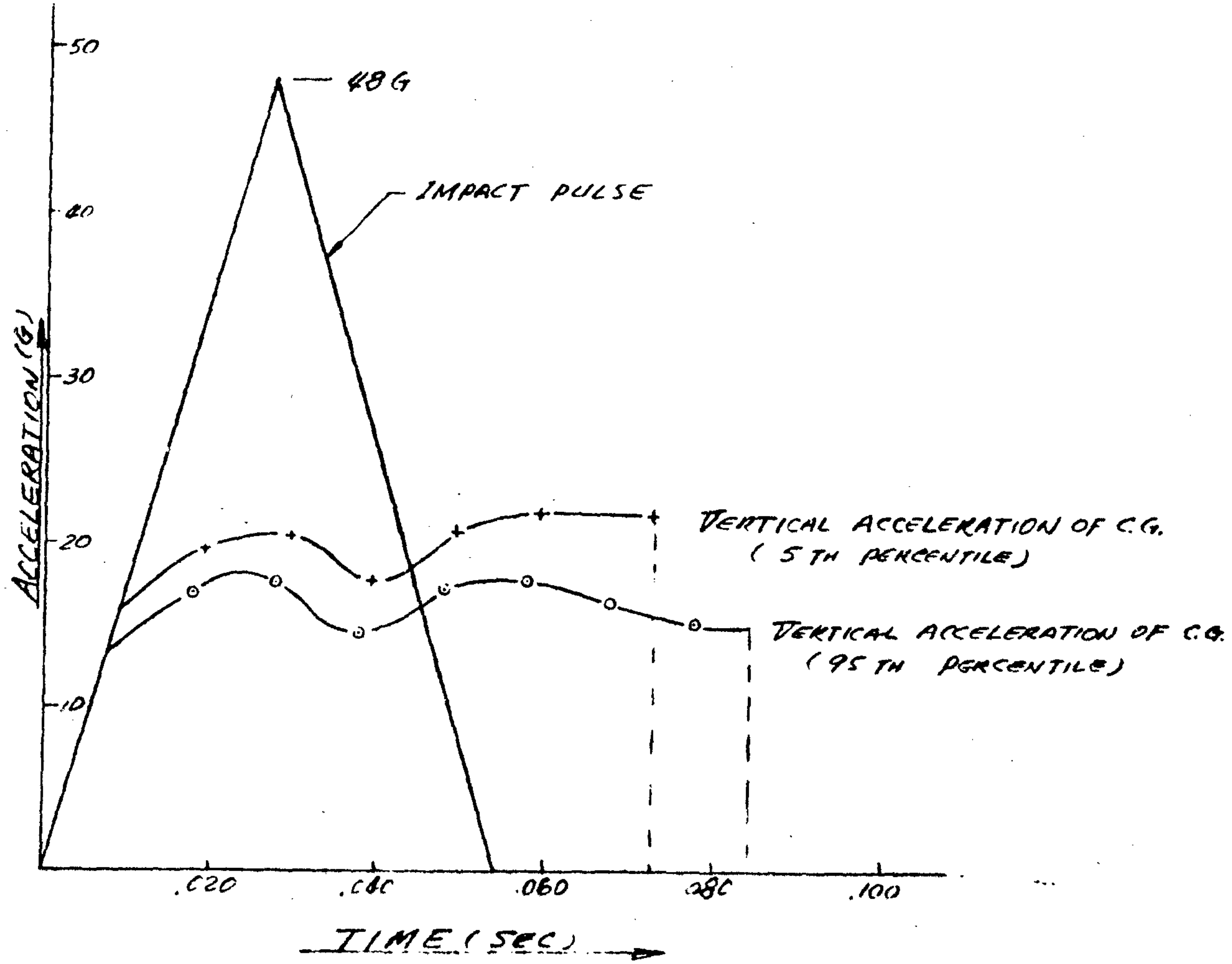


Figure 8. Acceleration Response In Vertical Impact.

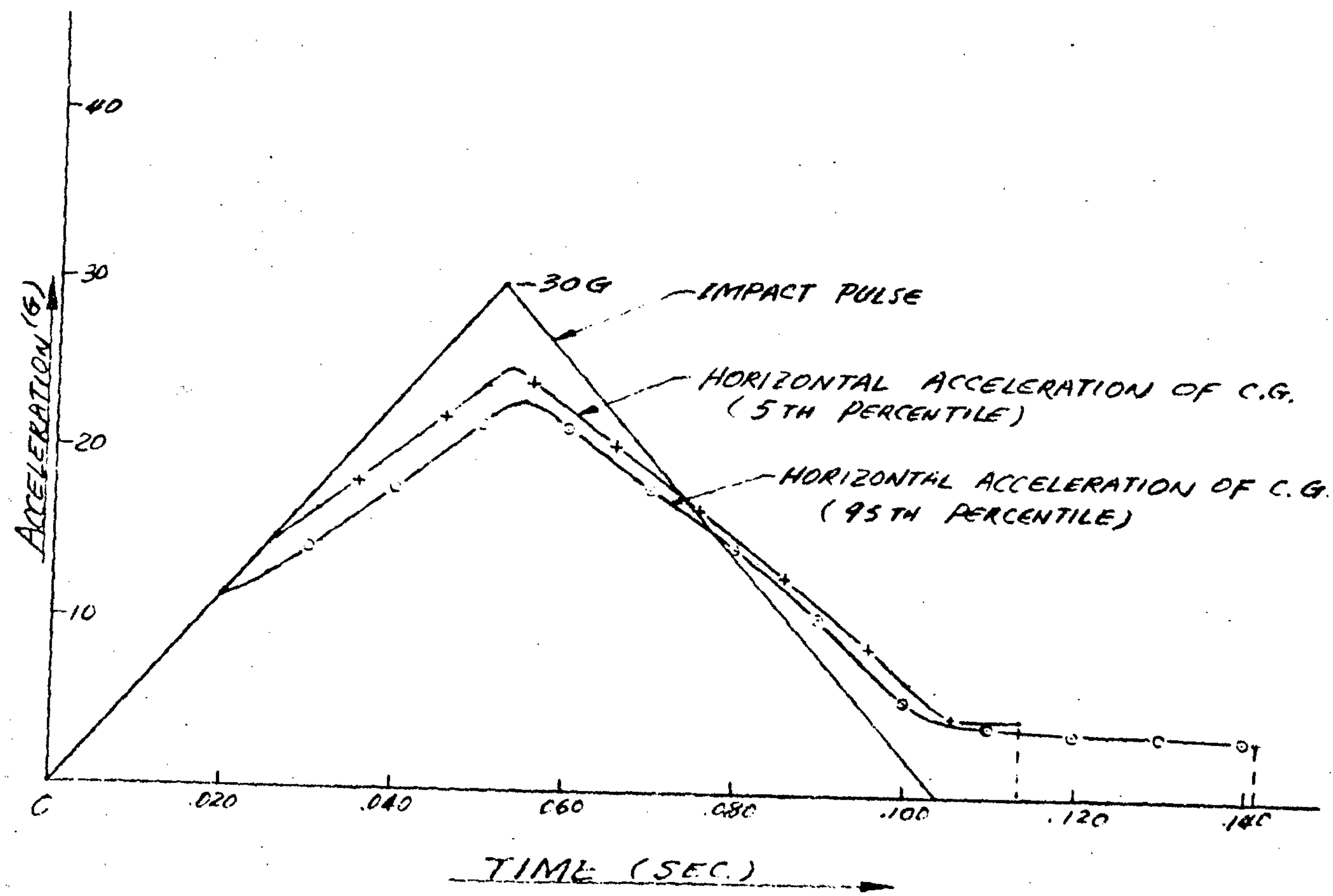


Figure 9. Acceleration Response In Horizontal Impact.

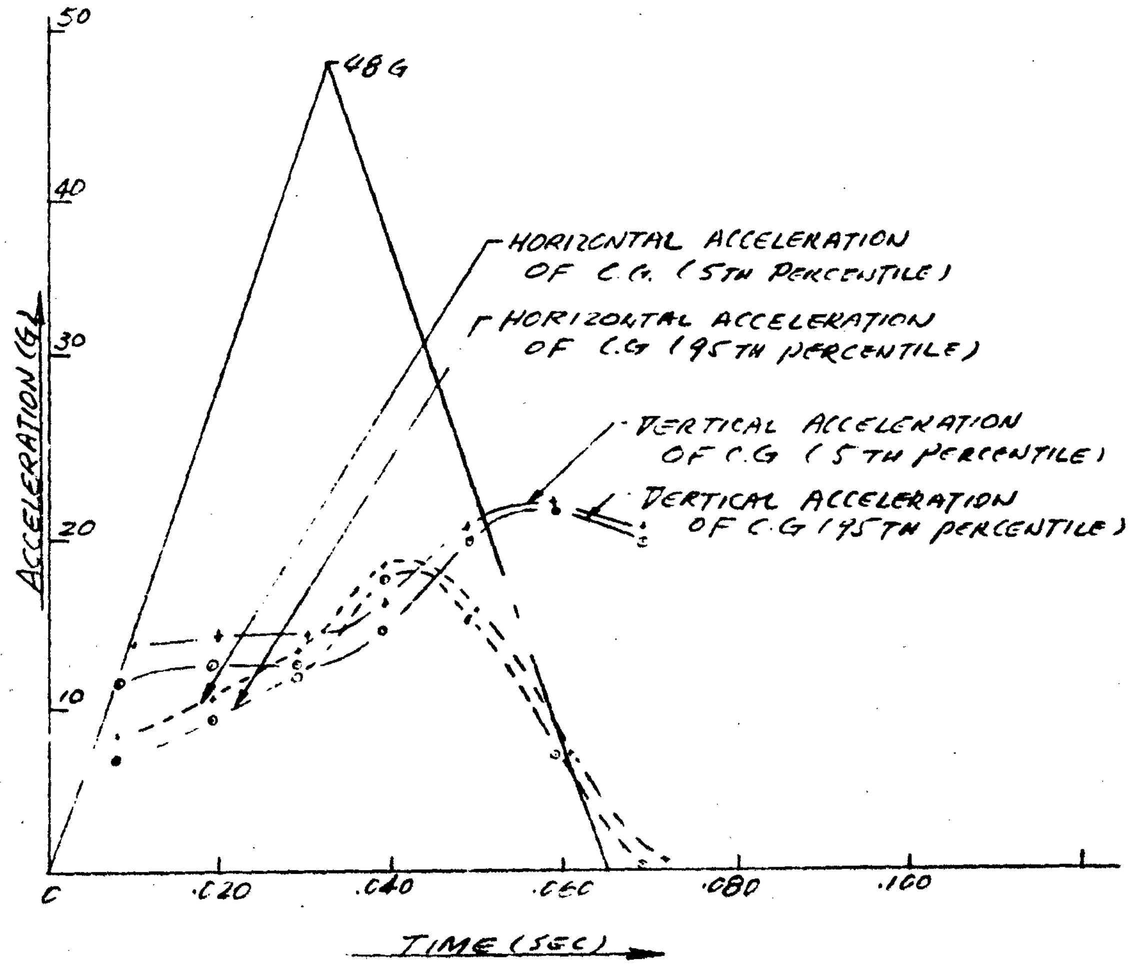


Figure 10. Acceleration Response In Oblique Angle Impact.

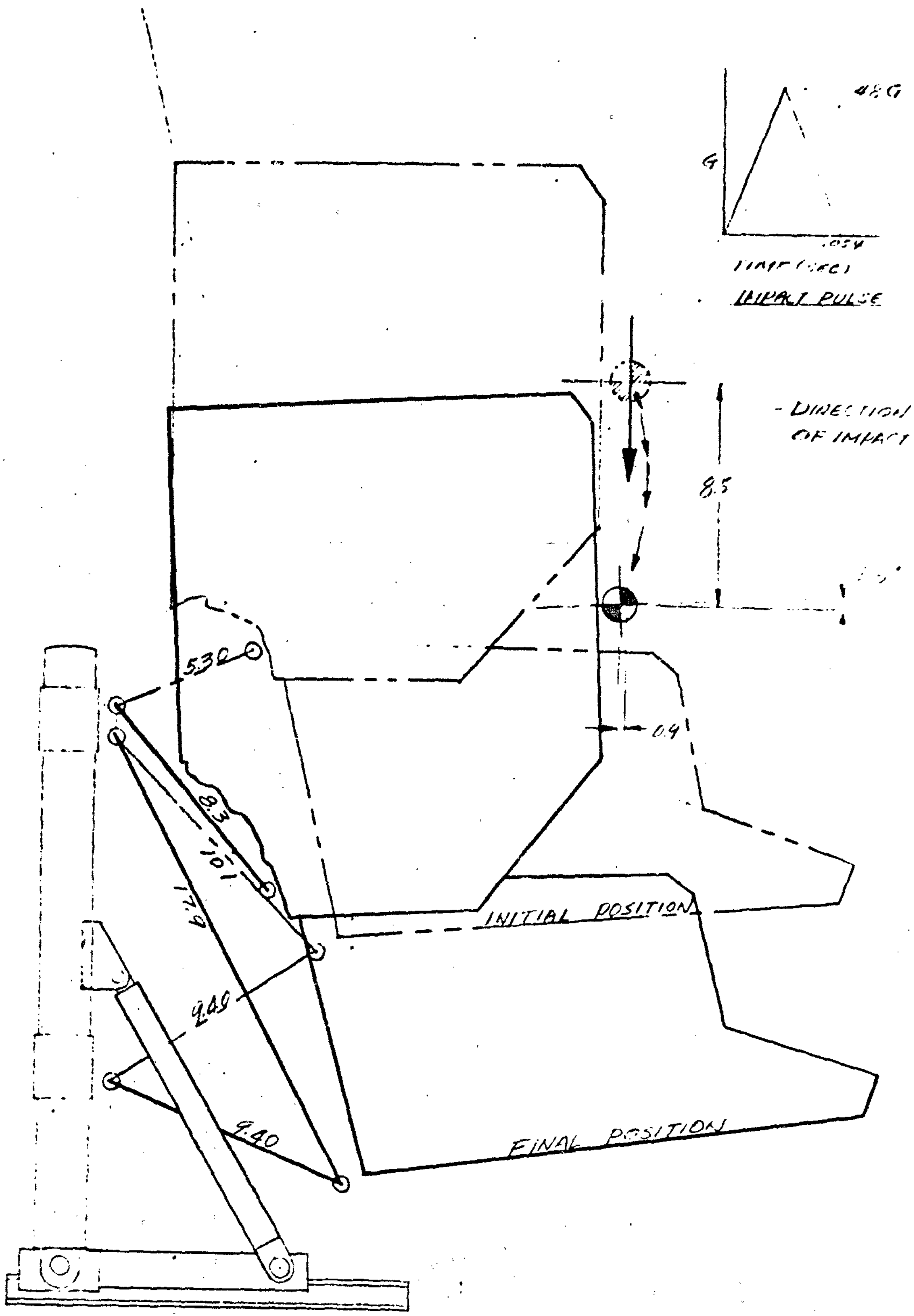


Figure 11. Seat Displacement in Vertical Impact - 95th Percentile.

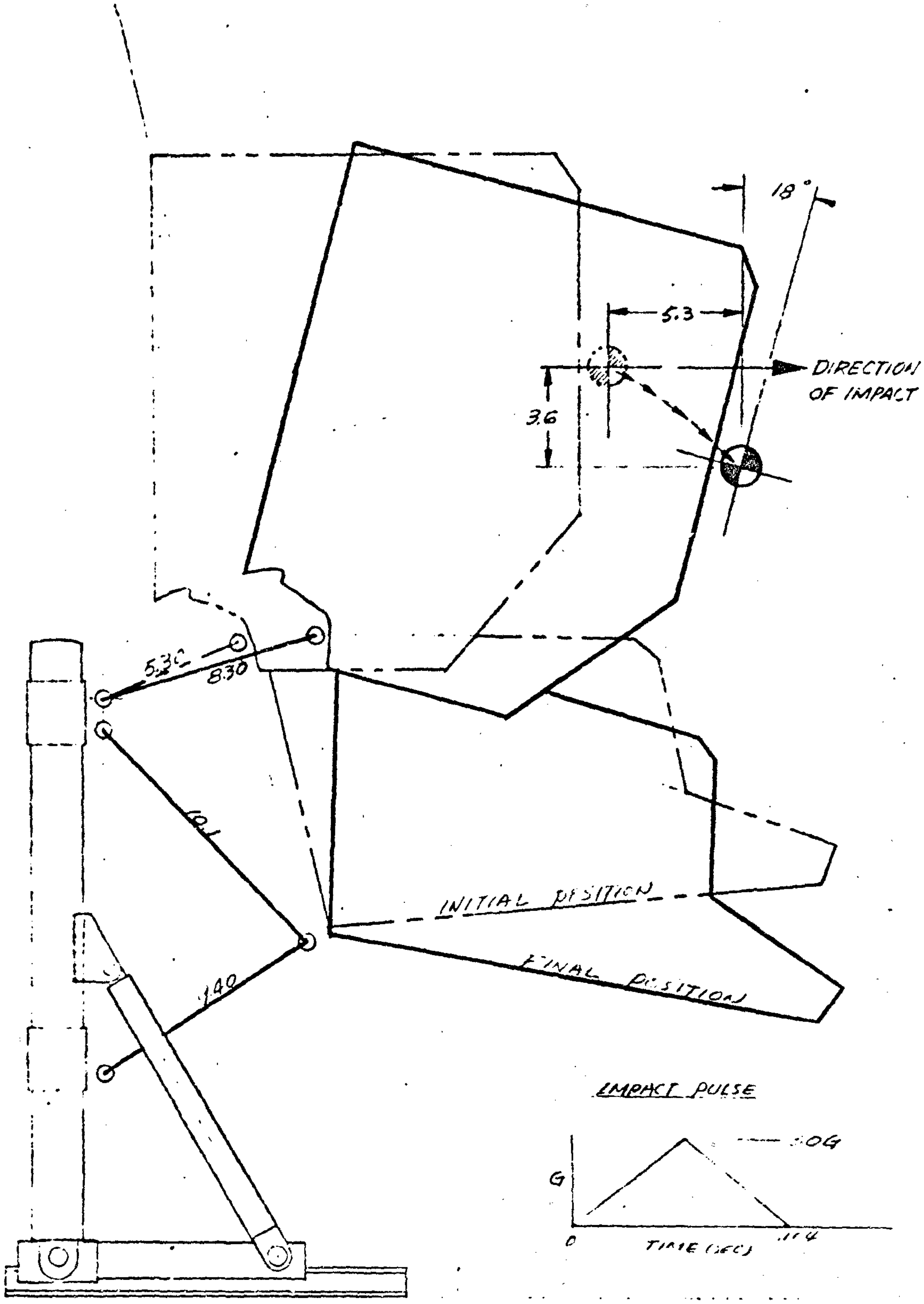


Figure 12. Seat Displacement in Horizontal Impact - 95th Percentile.

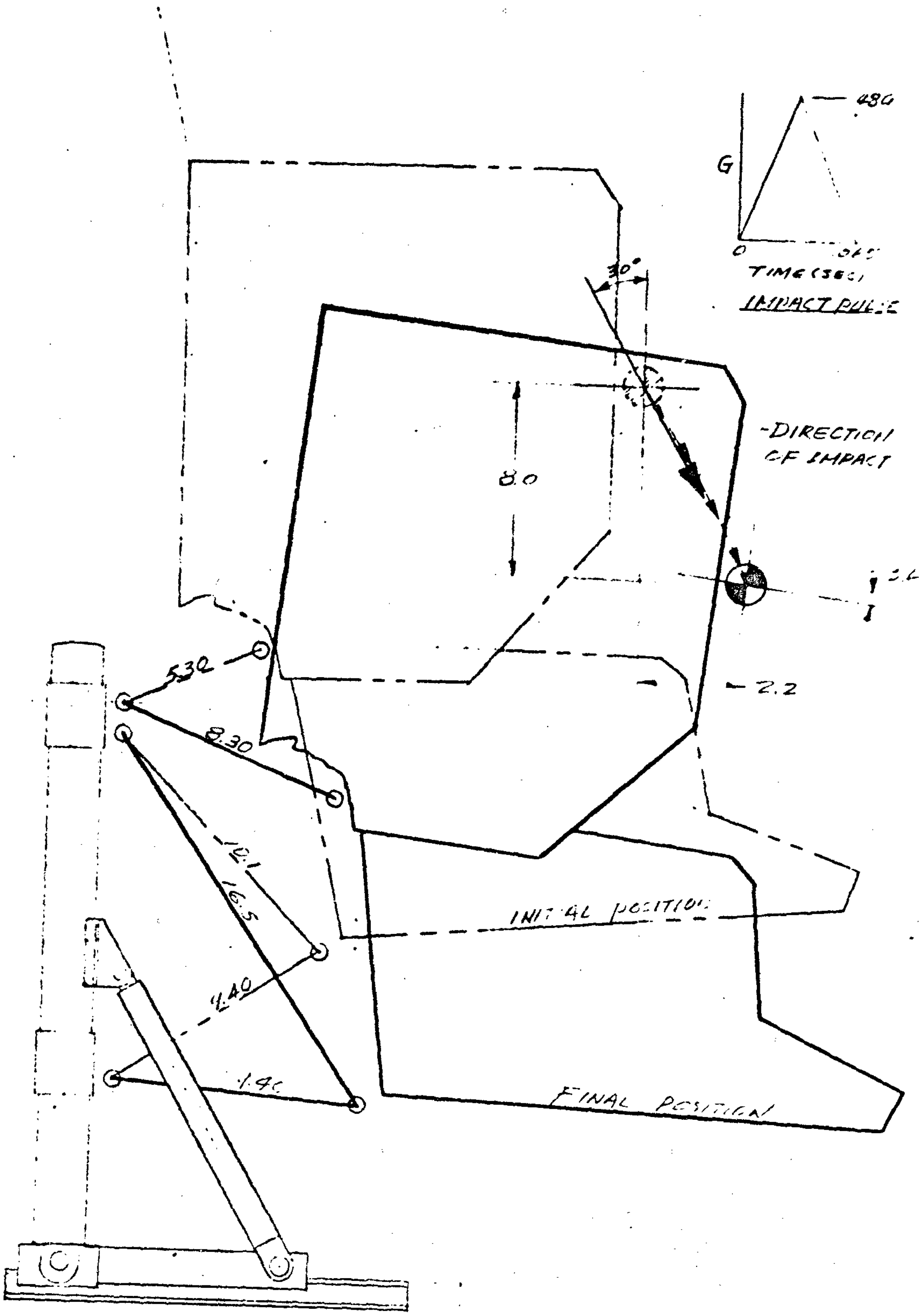


Figure 13. Seat Displacement in Oblique Angle Impact - 95th Percentile.

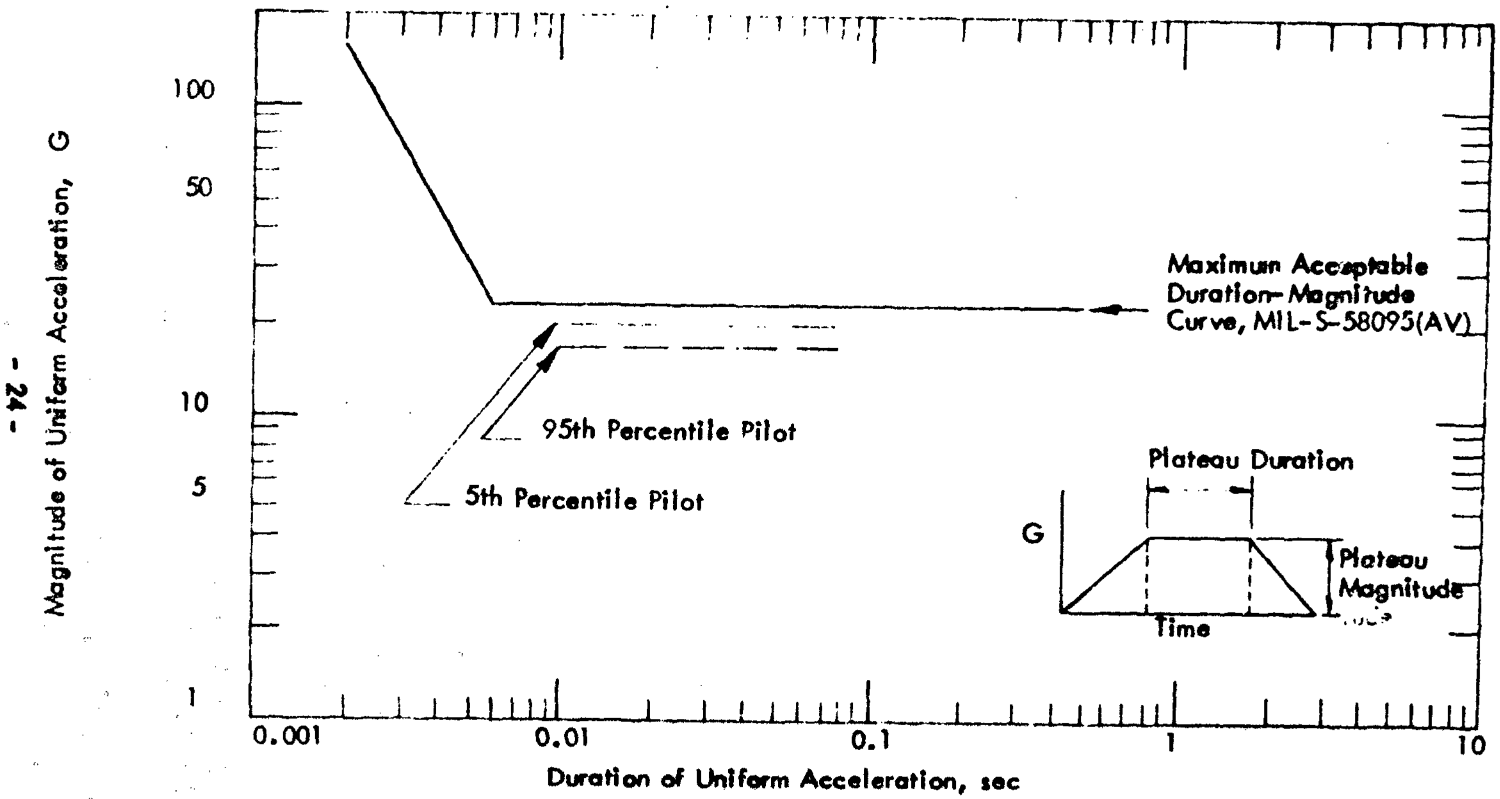


Figure 14. Human Tolerance to Vertical Accelerations

It is important to note that the pilot-bucket response curve shown in Figure 8 has the same general shape as the curve of the optimum energy absorber recommended in References 4 and 5. Due to the transient response of the occupant, an optimum energy absorber would be required to deflect at a higher force level early in the impact, and then yield at a lower level when occupant constraint force develops. This is to control the phenomenon known as dynamic overshoot of the occupant relative to the seat. One of the major assumptions made in constructing the mathematical model in the dynamic analysis was that the pilot and the bucket were treated as a simple rigid body. If further dynamic analyses should be required, the mass model should be revised to study the dynamic overshoot and to reflect the relative motion which exists between the pilot and the seat bucket.

In addition to calculating the dynamic response of the pilot-seat rigid body, the computer program also calculated the dynamic loads applied to the seat supporting frame during the impact. It is these loads that were used to analyze the stresses and to determine the size of the various numbers of the seat frame. The stress analysis is discussed in the following section.

V. STRESS ANALYSIS

The design loads of the frame members were obtained from the dynamic analysis described in the previous section. The detailed stress analysis is given in Appendix A. Unless otherwise stated, a safety factor of 1.5, relative to the yield strength of the material, was used in designing all load carrying members of the supporting frame. This safety factor was chosen because some uncertainty exists in the prediction of the dynamic loads due to the idealized assumptions made in the analytical model. In addition, loads used herein reflect only the

symmetric loading, which may be inadequate when the loads due to coupling between the symmetric and anti-symmetric conditions are introduced. A safety factor less than 1.5 is accepted in the final design of certain members only when the loads are clearly defined or are non-critical.

Except for the sliding rails, alloy steel AISI 4130 heat-treated to an ultimate strength of 180,000 psi was used in most of the structural critical parts. For non-critical parts, low carbon steel 1018 was used. The bottom rails were made of aluminum alloy 7075-T6 because of its excellent machinability and light weight. The design mechanical properties presented in Tables 2.3.1.1 (a) and 3.2.7.0 (f) of MIL Handbook 5 were used for the materials mentioned above. For steel joints welded after heat treatment, Tables 8.2.1.1.2 (a) and (b) of MIL Handbook 5 were used for the allowable strength near the weld. For material heat treated after welding, the allowable strength in the parent metal near a welded joint was taken to be equal to the allowable strength for the material in the heat-treated condition.

In some cases where MIL Handbook 5 denotes only the ultimate strengths, the corresponding yield strengths of AISI 4130 as given in Table 2.3.1.1. (a) of the same handbook are used. The yield strength in shear is also assumed to be equal to the ultimate strength in shear multiplied by the ratio of yield strength and ultimate strength in tension.

The engineering data on the response of the present energy-absorbing crew seat system to various types of impact is limited. In designing this seat frame structure, some conservative engineering judgements have been used. As more of engineering data of the seat becomes available, it will be possible to refine the system and use lower factors of safety in its design. This would result in a lower weight structure.

VI. DEVELOPMENTAL DYNAMIC TESTS

Upon completion of the design, complete seats were fabricated and tested on the ARA, Inc. drop tower and sled facility. The major accomplishments of this phase of work were the verification of the structural integrity of the seat frame and the establishment of the proper E/A loads for meeting the performance specifications of MIL-S-58095 (AV).

A photograph showing the position of the seat and dummy prior to a drop tower test is given in Figure 15. A 95th percentile male dummy was placed in the seat and the seat was then positioned in its rearmost horizontal location and its uppermost vertical location. The uppermost vertical location was chosen as it results in the maximum loads applied to the seat frame during an impact. All E/A lengths and the seat's location relative to the floor and frame were measured. The drop platform was then raised to the desired height and released. The G load on the seat frame was controlled by four large E/A's positioned at the bottom of the drop tower. After the impact, the lengths of all E/A's and the relative position of the seat were again measured. The difference between the initial and final positions is the motion of the seat.

Two drops were performed, 1A and 1B. After measuring the final position of the seat at the end of the test 1A and without repositioning the seat, the platform was raised again to the desired height and dropped constituting test 1B. In the test 1A, only one accelerometer was mounted on the platform to record the impact pulse on the seating frame. An additional accelerometer was mounted on the bottom panel of the bucket in the test 1B. Two switches at 6" apart were located right near the impact point so that the actual impact speed could be found. Table IV summarizes the impact and responses. It should be noted that the responses

Figure 15. Position of Seat and Dummy for ARA Drop Test

Table IV. Summary of Drop Tests.

Drop Test	1A	1B	Remarks
Drop Weight, lb.	830	830	Measured Input
Drop Height, in.	84	86	
Static E/A force in Bottom Platform, lb.	27200	27200	
Bottom Platform Movement, in	1.4	1.3	
Time to First Switch, sec.	0.656	0.656	Data Trace Reading
Time to Second Switch, sec.	0.681	0.681	
Input Pulse Duration, sec.	0.021	0.021	
Input Pulse Peak G	53.0	57.0	
Theoretical Impact Speed, ft/sec	21.2	21.4	Calculated from Drop Height
Actual Impact Speed, ft/sec.	20.4	20.4	Calculated from Distance Between Two Switches
Input Pulse Average G	30.2	30.2	Calculated fm. impact Spd. & Duration of Input Pulse
NSRP Displacement, Horizontal, in	1.30	0.05	Measured Responses
NSRP Displacement, Vertical, in	3.50	1.43	
Initial Thigh Target Angle, deg.	6	12	
Final Thigh Target Angle, deg.	12	17	
E/A Stroke, Top, in	0	0.10	
E/A Stroke, Middle, in	3.33	1.40	
E/A Stroke, Bottom, in	0	0	

of the seat in tests 1A and 1B are different because their initial positions are different. The structural integrity was maintained during the two drops. No single structural failure was detected. The 4-way seating adjustment functioned properly after the tests.

For horizontal impact testing, the seat was first attached to a specially designed horizontal impact sled. Figure 16 is a photograph showing the crew seat attached to the sled. For the test, the sled was accelerated to the desired velocity by pushing it with a truck. At a distance of 120 feet from the rigid barrier, the truck was braked allowing the sled to roll freely the remaining distance into the barrier. Sled guidance was provided by connecting the right front wheel of the sled to a guidance cable and a control arm. The G-level to which the seat was subjected was controlled by six E/A's (ARA's constant force TOR-SHOK energy absorber) mounted on the front of the sled. As in the drop tests, the seat was positioned in its rearmost horizontal location and its uppermost vertical location. All E/A lengths and the seat's location relative to the floor and frame were recorded before and after the test. The motion of the seat is then the difference between the initial and final positions. A 95th percentile male dummy was used to represent the pilot. To aid in the interpretation of the impact, high speed motion pictures were taken during the test.

A review of the slow motion pictures shows that the impact speed of the sled was 53.3 ft/sec. The sled and the seat were subjected to a constant 27.4 G pulse with a duration of 0.057 seconds. Table V summarizes the impact and responses of the seat during the sled test. It was observed that most of the kinetic energy of the seat was taken out by the top E/A members as expected from the dynamic analysis. The left side panel of the bucket became loose but remained

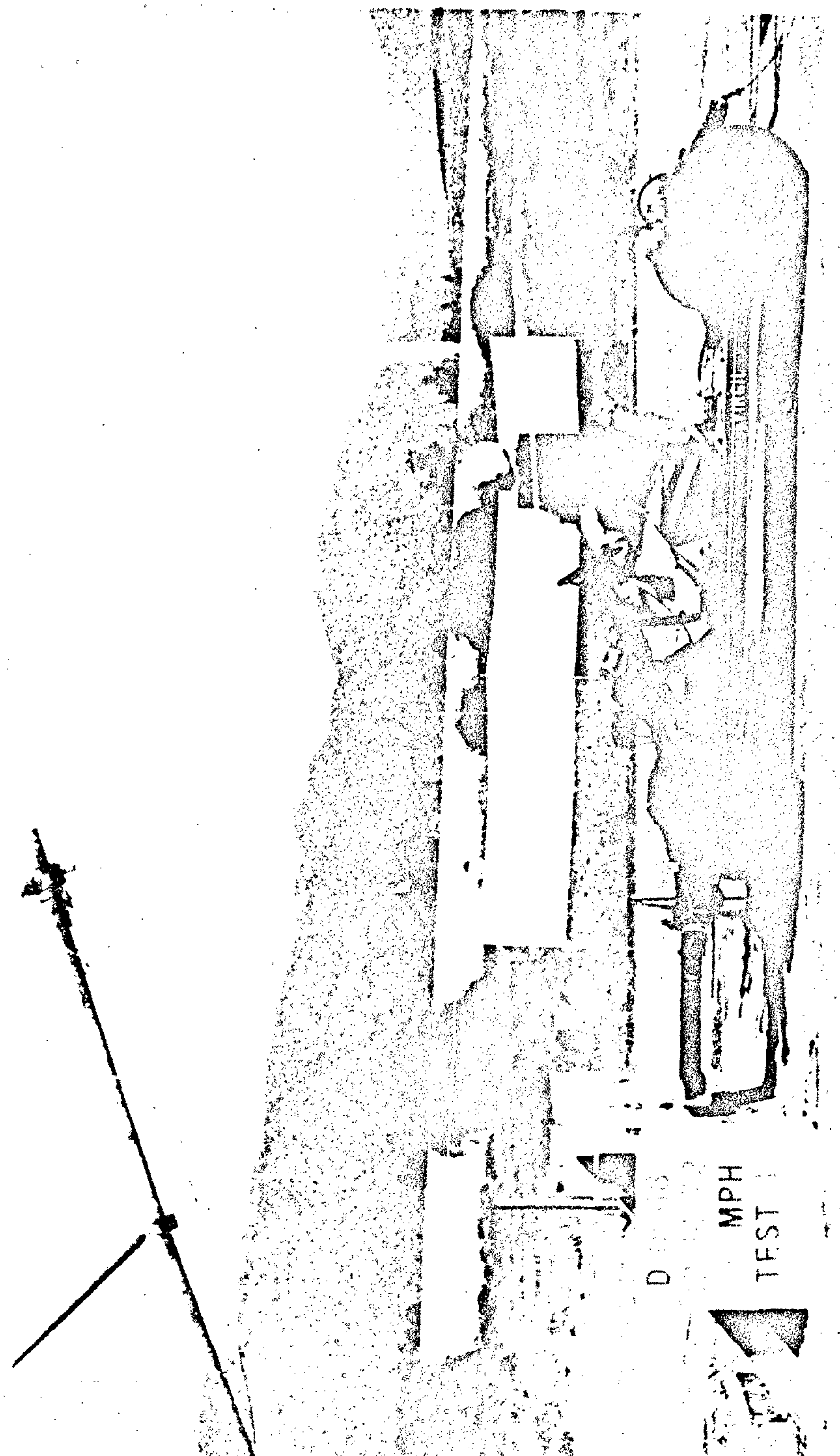


Figure 16. Horizontal Impact Test Sled

Table V. Summary of Horizontal Sled Test

INPUT	
Sled Weight, lb.	2300
Impact Speed, ft/sec	53.3
Impact Duration, sec	0.057
Sled Front E/A Force, lb	63000
Sled Front E/A Stroke, in	15.9

RESPONSE OF SEAT			
E/A Stroke, in		Top Left	1.95
		Top Right	2.00
		Middle Left	0.10
		Middle Right	0.25
Vertical Displacement in.	Rear Bottom Corner	Left	0.13
		Right	0.25
	Front Bottom Corner	Left	3.33
		Right	3.45
Horizontal Displacement in.	Rear Bottom Corner	Left	0.30
		Right	0.35
	Front Bottom Corner	Left	0.10
		Right	0.25
Thigh Tangent Angle, deg.		Left	4.9
		Right	-5.6 (Pitchdown)

on the bucket. The fact that the back panel of the bucket bent during the test indicates that the pitching of the upper torso due to the flexibility of the harness restraint system added an angular acceleration to the 27 G horizontal acceleration. Again, no structural failure in the seat frame was detected and the seat adjustment mechanisms worked properly after the impact.

The impact at a speed over the required 50 ft/sec as stated in Reference 1 demonstrated the structural integrity of the crew seat frame. The basic engineering concept of attenuating the G-load experienced by a pilot during the impacts through the use of a system of E/A's was verified by this series of vertical and horizontal impact tests.

VII. ENVIRONMENTAL TESTS OF SEAT SYSTEM

Prior to the full acceptance of any crashworthy armored fixed seat for installation in an aircraft, certain environmental tests must be conducted to verify the adequacy of the seat to those environmental conditions described in MIL-S-58095(AV) and MIL-STD-810B, Notice 1. Based on these two documents the following environmental tests were conducted:

A. High Temperature Test

B. Low Temperature Test

C. Humidity Test

D. Fungus Test

E. Salt Fog Test

F. Dust Test

G. Vibration Test

The tests were conducted by Ogden Technology Laboratories, Inc. during a period from 19 December 1972 to 23 February 1973. A U. S. Government

Representative witnessed all the tests. An Ogden prepared report, No. F-72683 was submitted to ARA, Inc. and a copy of this complete report is provided in Appendix B. In summary, this report states that the seat frame completed the test program without visible evidence of any physical damage or deterioration. After the seat had experienced all the environmental tests, each TOR-SHOK was activated individually and the running loads on each were found to be within ± 7% of the loads measured originally prior to the environmental tests. Based on these measurements, the seat frame assembly met all requirements of MIL-S-58095(AV) and MIL-STD-810B, Notice 1. Finally it should be noted that in order to meet the vibration test requirements, a complete seat assembly using the armored bucket, and restraint system as well as an anthropormorphic dummy was utilized in the test to properly simulate the loading conditions on the frame assembly.

VIII. SUMMARY OF NADC ACCEPTANCE TESTS

Crash load tests of pilot and co-pilot models of the crashworthy armored seat were conducted at the NAVAIRDEVCEN (Naval Air Development Center) horizontal accelerator and drop tower facilities located at Philadelphia, Pa.

"A 95th percentile ballasted anthropomorphic dummy (Alderson CG95QA) weighing 213.5 lbs., with flight suit, APH-5 helmet, and shoes, was used for all tests. The restraint system consisted of a conventional 3 inch wide lap belt (Type IV per MIL-W-25361, modified to facilitate attachment of the belt directly to the bucket), and 1-23/32 inch wide shoulder straps (Type VIII per MIL-W-4088). The major modification to the lap belt was the location of the belt length adjusters near the attachment release bucket at the center of the lap belt.

Monitored data included input acceleration at the drop tower base or sled deck, input acceleration at the seat mount plate, triaxial dummy and seat

accelerations, and selected energy attenuation loads."

During the drop tower tests a modification to the upper TOR-SHOKs were required in order to prevent the seat from bottoming out on the deck. The modification consisted of placing "stop" rings on the outer and inner tubes of the TOR-SHOKs. With this arrangement the upper TOR-SHOKs could not break loose as was evidenced during Test 1 and Test 2 on the drop tower. Once the rings were installed, the two drop tower tests were repeated and the seat operated properly.

During the sled tests the rod ends attached to each end of the TOR-SHOK were failing due to improper heat-treat of the body portion of the rod end. When all of the rod ends were replaced with properly heat-treated ball joints, the seat operated as designed for all of the sled tests.

A summary of the test acceleration data obtained from the drop tower and sled tests is provided in Table VI. Test Nos. 1A and 2A represent the two drop tower tests with the upper TOR-SHOKs modified with the "stopping"rings. Tests 3B and 4 represent the two sled tests with the added change of replacing the rod ends on all TOR-SHOKs with properly heat-treated components. Additional information is provided in Table VII for the same four tests with respect to the loads and maximum displacements of the TOR-SHOKs.

The most important acceleration traces are those associated with the combined angle drop tower test (Test #1A). The acceleration traces for this case are provided in Figure 17. In addition the associated TOR-SHOK force measurements are provided in Figure 18.

A detailed description of each of the tests has been summarized in a letter from the Commander, Naval Air Development Center to the Commanding General, U. S. Army Aviation Systems Command. "Eight dynamic tests of the armored

Table VI

ARMY ARMORED E/A CREWMAN SEAT

TEST RESULTS - ACCELERATION RECORD

TEST NO.	TEST DESCRIPTION	SEAT POSITION	PEAK G-LEVEL: SEAT BUCKET			PEAK G-LEVEL: DUMMY PELVIS		
			VERT.	HORIZ.	LAT	VERT.	HORIZ.	LAT.
1A	COMBINED ANGLE DROP TEST $\Delta V = 50.2$ FT/SEC $G_{MAX} = 47.5$	LOWEST VERT.	* 41.2 / 18.5	30.5	11.0	* 38.0 / 25.0	20.0	7.0
2 A	VERTICAL DROP TEST $\Delta V = 44$ FT/SEC $G_{MAX} = 49.5$	HIGHEST VERT	* 450 / 22.0	20.0	7.6	* 36.0 / 19.6	14.0	1.7
3 B	COMBINED ANGLE SLED TEST $\Delta V = 49.2$ FT/SEC $G_{MAX} = 28.8$	LOWEST VERT MOST REARWARD	20.2	32.7	13.5	13.8	27.7	14.0
4	FORWARD SLED TEST $\Delta V = 48.3$ FT/SEC $G_{MAX} = 29.5$	HIGHEST VERT MOST REARWARD	15.6	30.8	6.8	13.0	37.8	3.0

NOTES.

* $\frac{\text{PEAK}}{\text{AVERAGE}}$ SHOWN

Table VII

ARMY ARMORED E/A CREWMAN SEAT

TEST RESULTS - E/A LOAD AND DISPLACEMENT

TEST NO.	RIGHT HAND SIDE E/A						LEFT HAND SIDE E/A					
	TOP		MIDDLE		BOTTOM		TOP		MIDDLE		BOTTOM	
	LOAD AVG/PK (LBS)	STROKE (IN)	LOAD AVG/PK (LBS)	STROKE (IN)	LOAD AVG/PK (LBS)	STROKE (IN)	LOAD AVG/PK (LBS)	STROKE (IN)	LOAD AVG/PK (LBS)	STROKE (IN)	LOAD AVG/PK (LBS)	STROKE (IN)
1A	— / *5520	3.0	— / 2400	5.2	NM	0	— / *9924	2.9	— / 2267	4.3	NM	0
2A	— / *16072	2.4	1334 / 2878	7.0	NM	0	— / *13776	2.6	1449 / 2318	7.4	NM	0
3B	NM	18	NM	0.5	NM	0	— / 7325	3.0	— / 1970	0	— / *4635	1.70
4	— / *7340	2.5	NM	0	NM	0	— / *11,000	3.0	NM	0	NM	0

NOTES:

* READING DID NOT RETURN TO ZERO

NM - NOT MONITORED

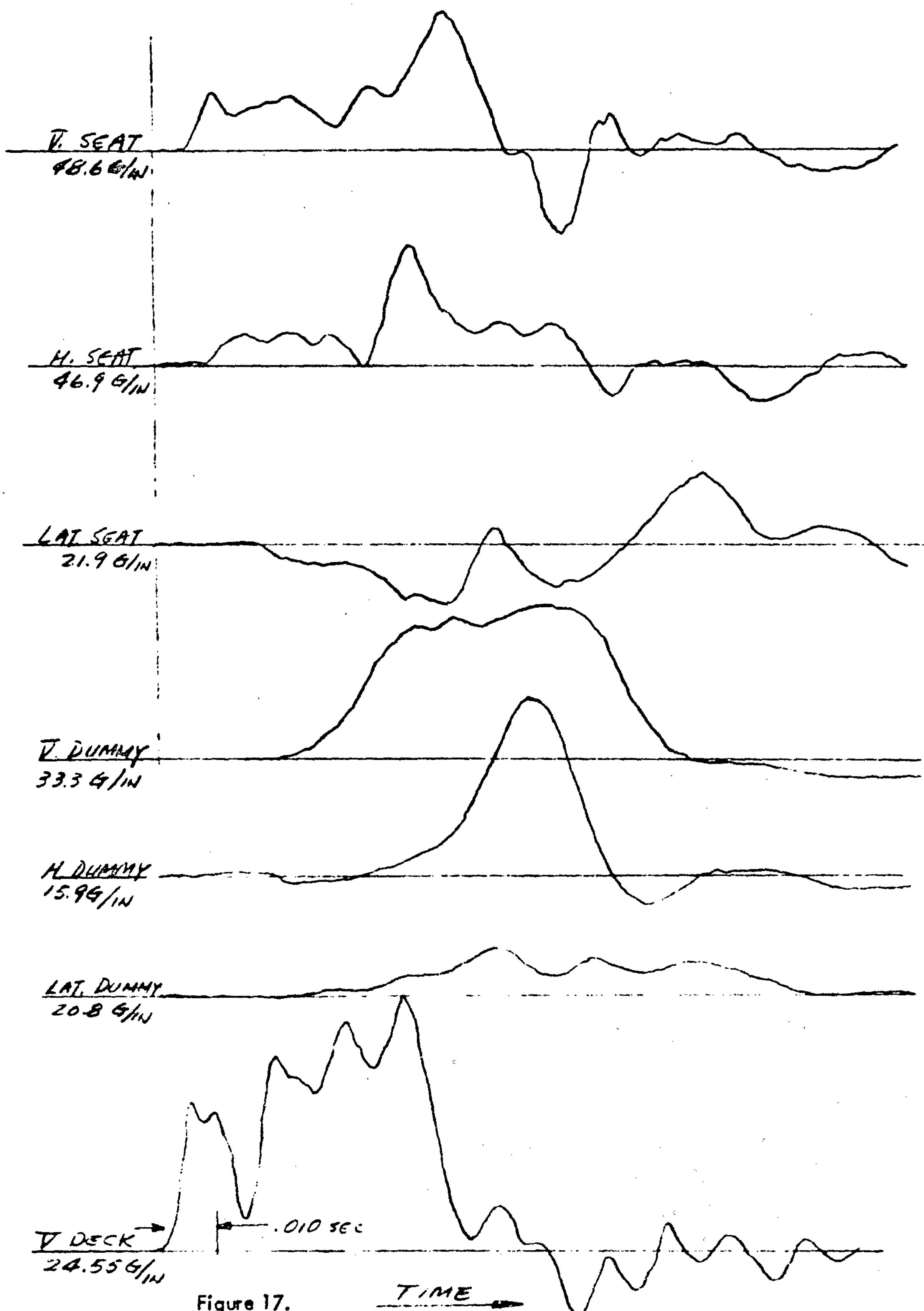


Figure 17.

ACCELERATION RECORD - TEST # 1A
COMBINED ANGLE DROP TEST

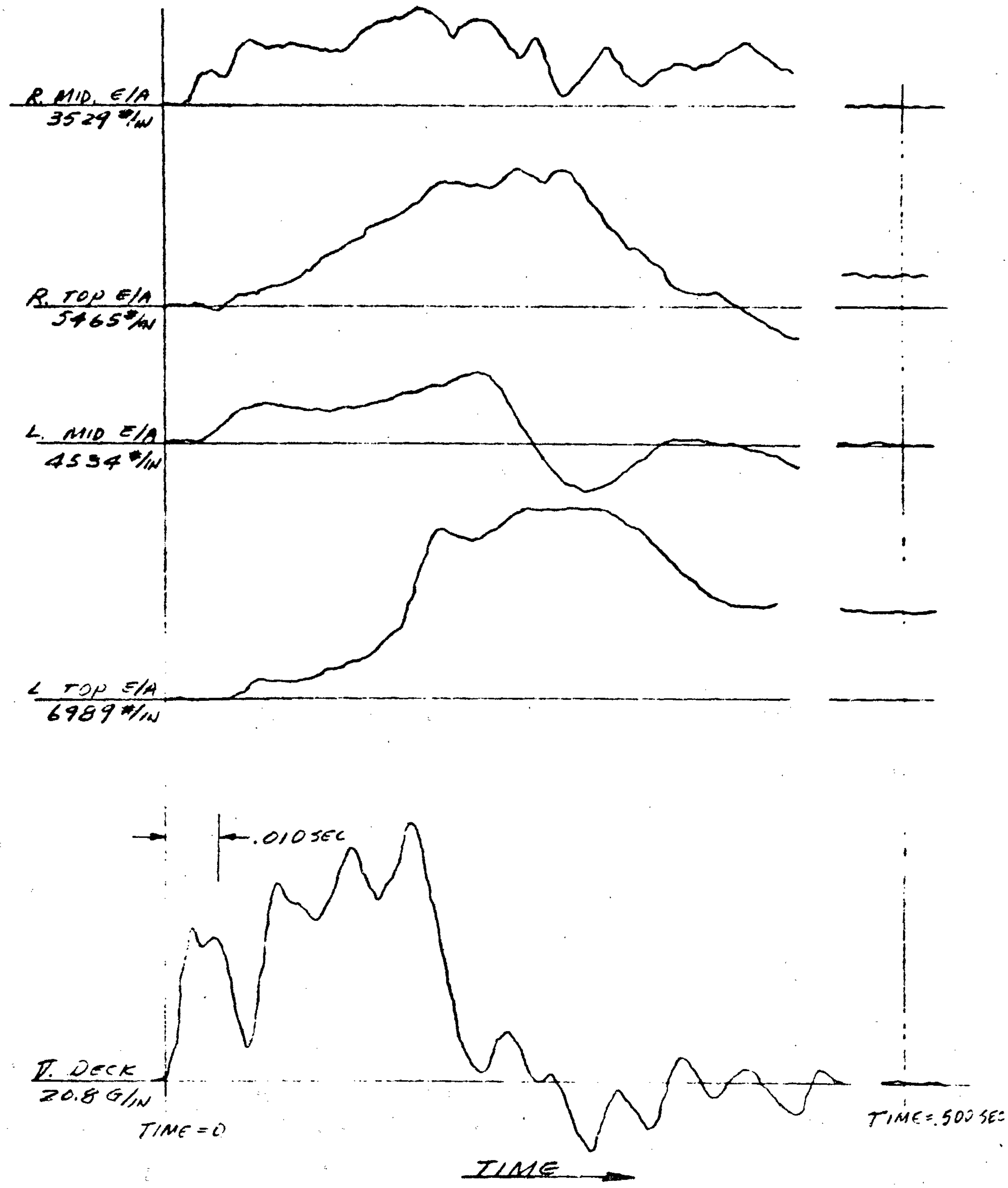


Figure 18. E/A LOAD RECORD
TEST #1A COMBINED ANGLE DROP TEST

crashworthy seat were conducted from 10 April 1973 to 30 May 1973, four tests on the drop tower and four on the horizontal accelerator. The seat system was to be qualified in accordance with MIL-S-58095(AV). Two objectives were required for the dynamic tests: (a) no loss of structural integrity of the seat system, and (b) limitation of the seat pan acceleration to a value not in excess of human tolerance to vertical acceleration." Excerpts of the NADC letter to AVSCOM concerning the tests are provided herein in order to provide detailed information.

A. Combined Angle Drop Tower Tests (1 and 1A)

Photographs of the installation for this test are shown in Figure 19 prior to impact, and in Figure 20 after impact. "The bucket was tested in the full-down position and rear most adjustment with respect to the rails. This aft horizontal position was used for all subsequent tests. To preclude the possibility of complete breakaway of the side panel armor from the seat system, the following modifications and precautionary measures were taken for all tested seats: (1) The aft side panel adjustment hole (position used for all tests) was reamed out to a depth of 1/4 inch to insure positive locking of the spring-loaded adjustment pin, and (2) a 3/16 inch hole was drilled in the side panel lip to permit the attachment of a safety line which would preclude breakaway of the panel but not affect normal operation."

"Test 1 resulted in stroking and separation of the top pair of TOR-SHOK E/A's. Separation occurred at the end of the impact pulse and was followed by impact of the right forward corner of the bucket with the deck. The pitching motion of the bucket caused the bottom TOR-SHOKs to come in contact with the horizontal adjustment actuator arm deforming it, however, the seat remained firmly locked in position at all times. It was concluded that the upper E/A's required a modification to keep the inner and outer tubes from separating."

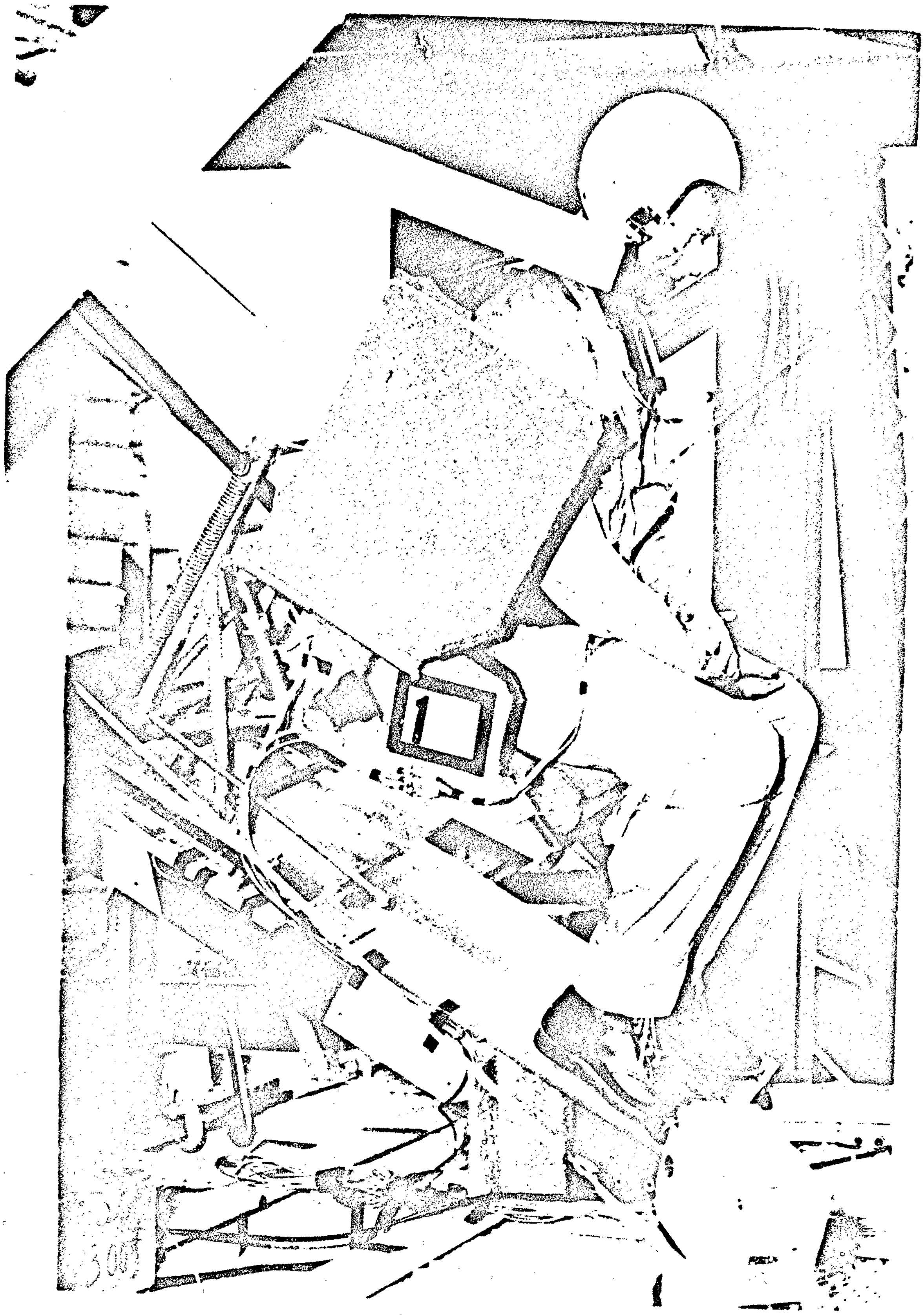


Figure 19. Combined Angle Drop Tower Test Configuration Prior to Impact

Figure 20. Combined Angle Drop Tower Test Configuration After Impact

"Test 1A a repeat of Test 1, was conducted with modified upper E/A's which were designed so that they would not separate at the end of stroking"

"The bucket impacted the deck at the right forward corner. Measured downward deflection of the seat was 6-5/16 inch on the right side and 4-5/8 inch on the left side. The forward pitching motion of the bucket caused the bottom TOR-SHOKs to contact and deform the horizontal adjustment actuator arm. The seat remained firmly locked in position throughout the crash test with the dummy restrained in the seat. It was concluded that the seat met the intent of the Test 1 condition of MIL-S-58095(AV)."

B. Vertical Drop Tower Tests (2 and 2A)

Photographs of the installation for this test are shown in Figure 21 prior to impact and in Figure 22 after impact. The bucket was tested in the full-up position and rear most adjustment with respect to the rails. The vertical input crash pulse simulated the pulse required in MIL-S-58095(AV).

Test 2 was conducted with a co-pilot model seat using the unmodified upper TOR-SHOK E/A's. "The test resulted in stroking and separation of the top and middle pairs of TOR-SHOKs. E/A separation was immediately followed by bucket impact with the deck."

Test 2A, a repeat of Test 2 was conducted with modified upper E/A's identical with those used in Test 1A.

"Inspection of the seat after the test showed it to be intact and firmly attached to the floor track. No portion of the seat contacted floor structure and the dummy was restrained by the shoulder and lap belt. Measured downward deflection of the seat was 7-9/16 inch on the right side and 8-1/2 inch on the left side. Because of the large vertical displacement resulting from this test condition, the top TOR-SHOKs made contact with the middle TOR-SHOKs during seat stroke and were indented. It was concluded that the seat functioned within the design specifications and withstood the vertical crash pulse, Figure 23."

Figure 21. Vertical Drop Tower Test Configuration
Prior to Impact

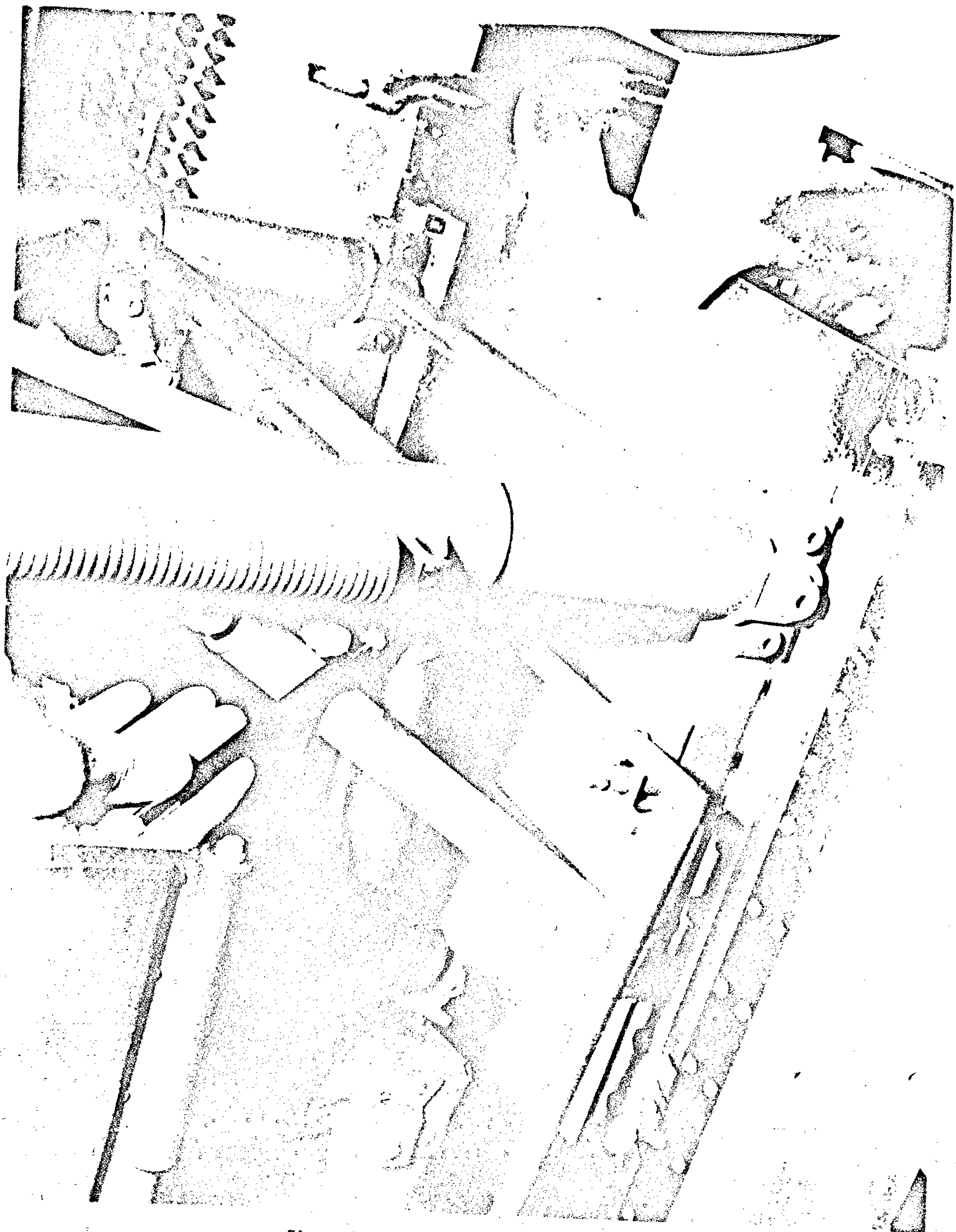


Figure 22. Vertical Drop Tower Test Configuration After Impact

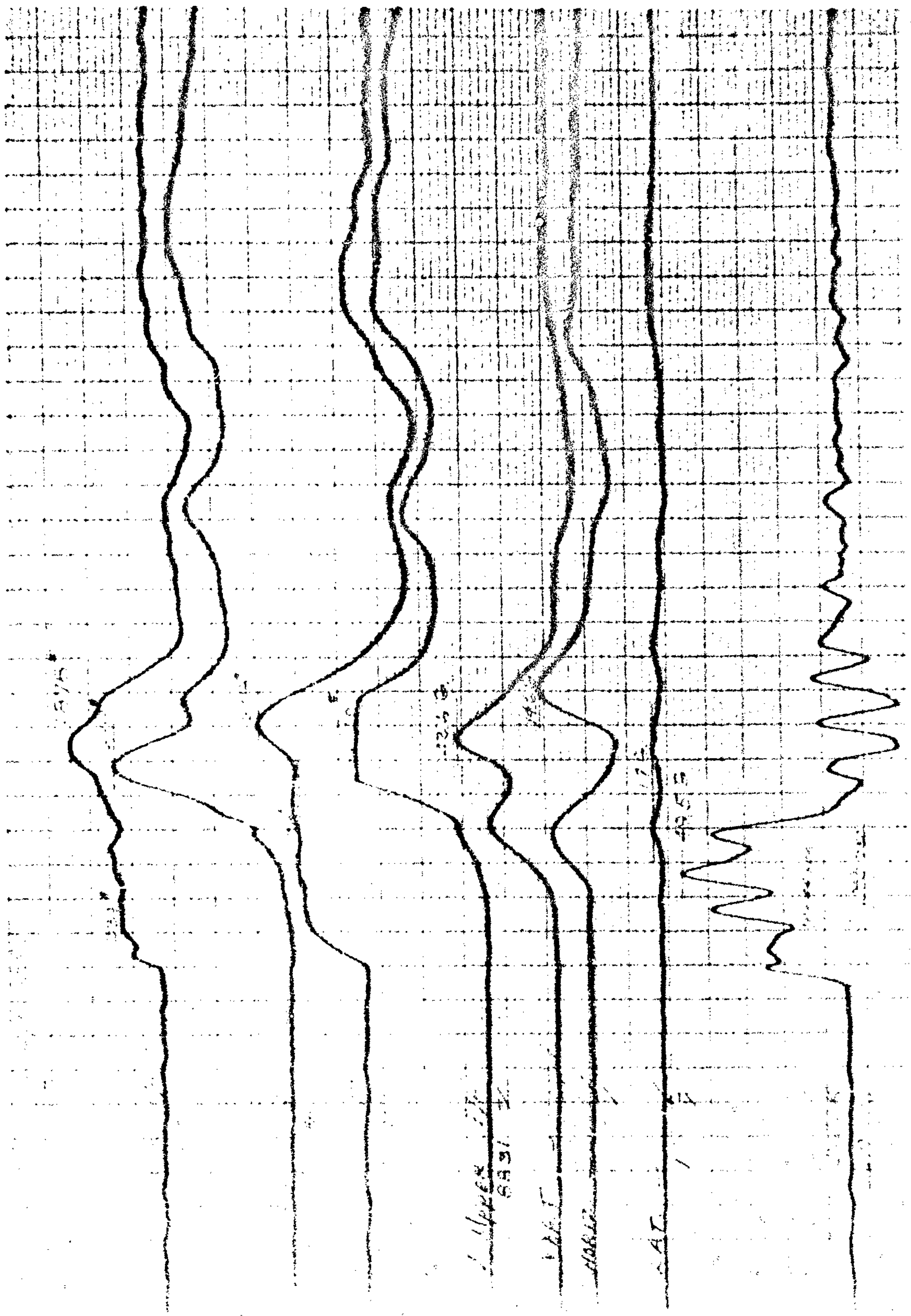


Figure 23. Vertical Drop Tower Test 2 A

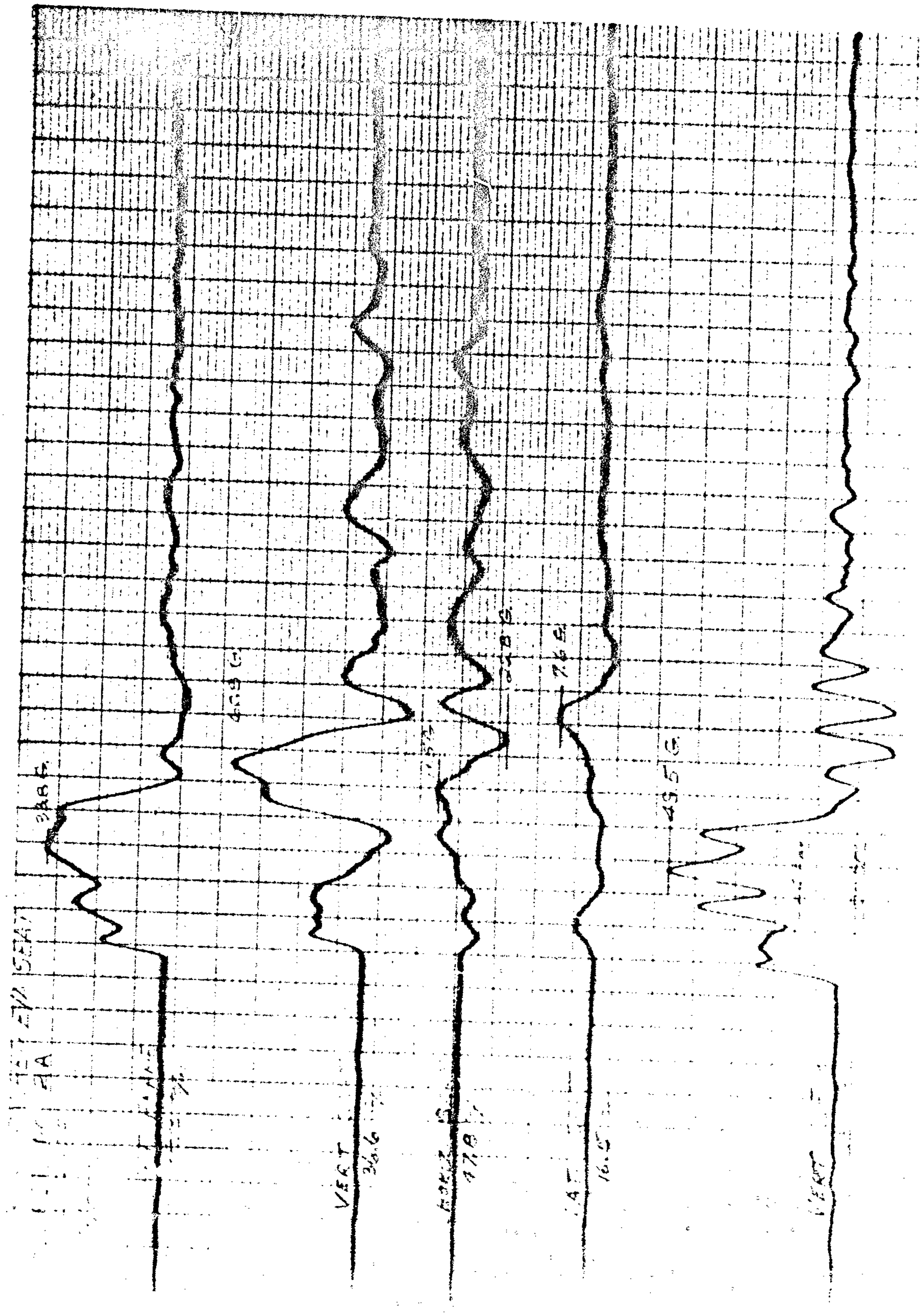


Figure 23 .Vertical Drop Tower Test 2A

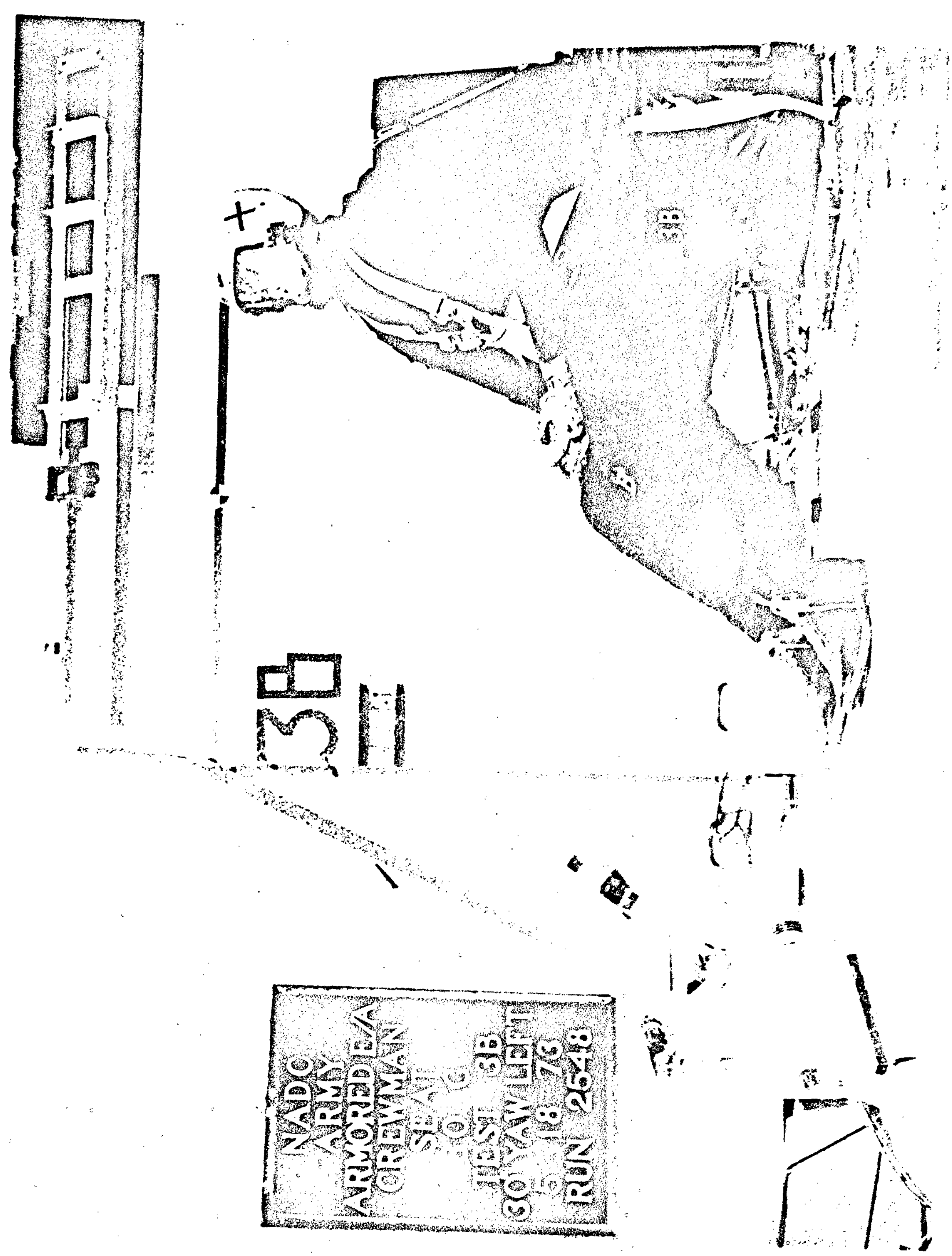


Figure 24. Combined Angle Sled Test Configuration
Prior to Impact

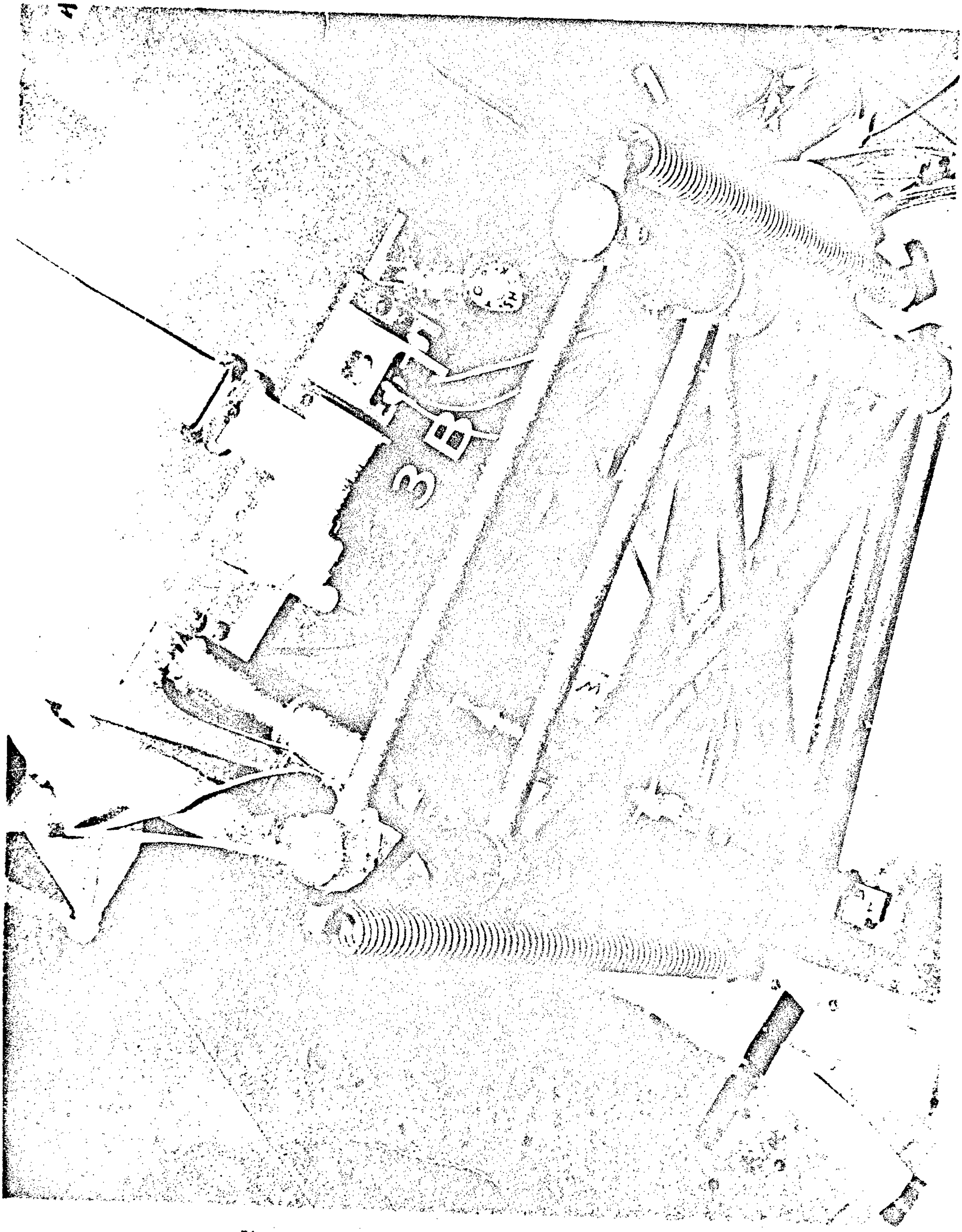


Figure 25. Combined Angle Sled Test Configuration
After Impact

C. Combined Angle Sled Tests (3, 3A and 3B)

Photographs of the installation for these tests are shown in Figure 24 prior to impact and in Figure 25 after impact. The seat was subjected to the Test 2 condition of Table iV of MIL-S-58095(AV).

Test 3 and its repeat, Test 3A resulted in the failure of the bucket attachments to the TOR-SHOKs. Specifically, the ball joint rod ends failed because of insufficient heat treatment.

Test 3B was conducted with modified rod ends rated at 11,000 lbs. "Inspection of the seat after the test disclosed that the port side rail partially failed in Test 3B just before the end of the input pulse. Analysis of the data and camera coverage indicated that the threads of the tiedown bolts were stripped prior to the shear failure of the rail. Inspection of the seat after the test showed that it was intact and still attached to both rails. The damaged port side rail warped the seat so that the right forward corner of the bucket was tipped toward the deck. The dummy was fully restrained by the shoulder and lap belts. It was concluded that the seat met the intent of the Test #2 conditions of MIL-S-58095(AV). Figure 26."

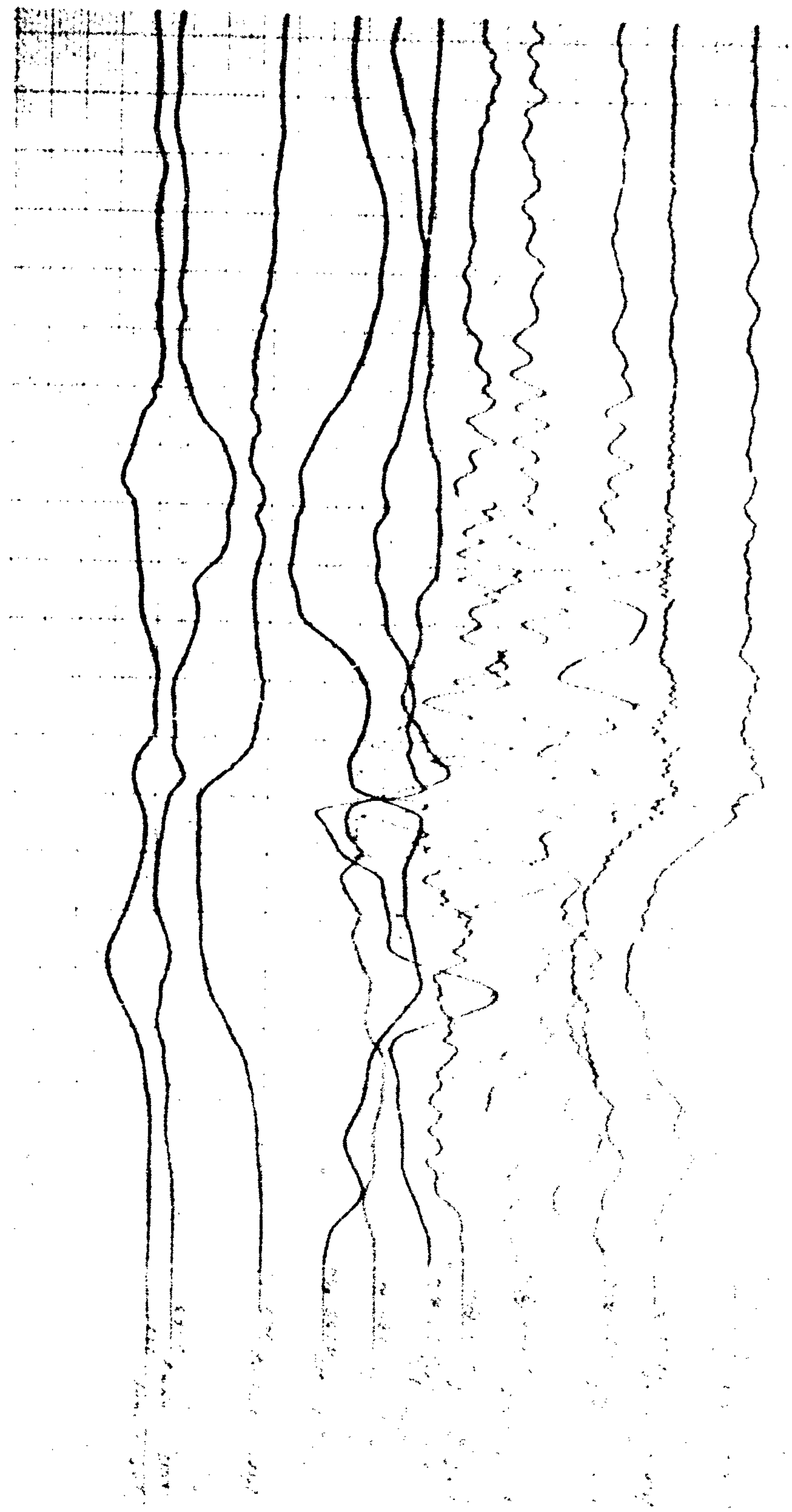


Figure 26. Combined Angle Sled Test 3 B

D. Forward Sled Test (4)

Photographs of the installation for this test are shown in Figure 27 prior to impact and in Figure 28 after impact.

"The seat was subjected to the Test #2 condition of Table IV of MIL-S-58095(AV). The bucket was tested in the full-up position. Because of the failure of the rail mount bolts experienced in Test 3B, the coarse-threaded 1/4 inch bolts were replaced by MS-20004 allen bolts. Inspection of the system after the test event showed the seat to be intact with the dummy restrained by the harness straps. The cantilevering action of the dummy on the forward edge of the bucket plus the inertia load of the side panel assembly were sufficient to pull out some bolts retaining the seat back to the right side and rear of the seat pan. Five bolts along the right inboard side of the seat and six bolts along the bottom of the seat back pulled out of their tapped holes. However, the seat back and side remained attached. It was concluded that the seat met the design specification and performed satisfactorily, Figure 29." This was the last test conducted by NADC on this seat program.

In summarizing the NADC acceptance test program, the following general remarks are provided by the NADC letter report:

"The system was to be evaluated in terms of structural integrity and the limitation of vertical accelerations on the seat system occupant. Tests 1A, 2A, 3B and 4 all met the criteria for seat structural integrity and dummy retention.

Although no test resulted in the breakaway of a component from the seat system, deceleration of the bucket in Tests 1, 2, 3 and 3B was momentarily uncontrolled due to previously noted failures. The bucket impacted the deck in Tests 1, 2, 1A, 3, 3A and 3B. With the exception of Test 2, the bucket was in the full-down position with an available clearance of 8 inches for

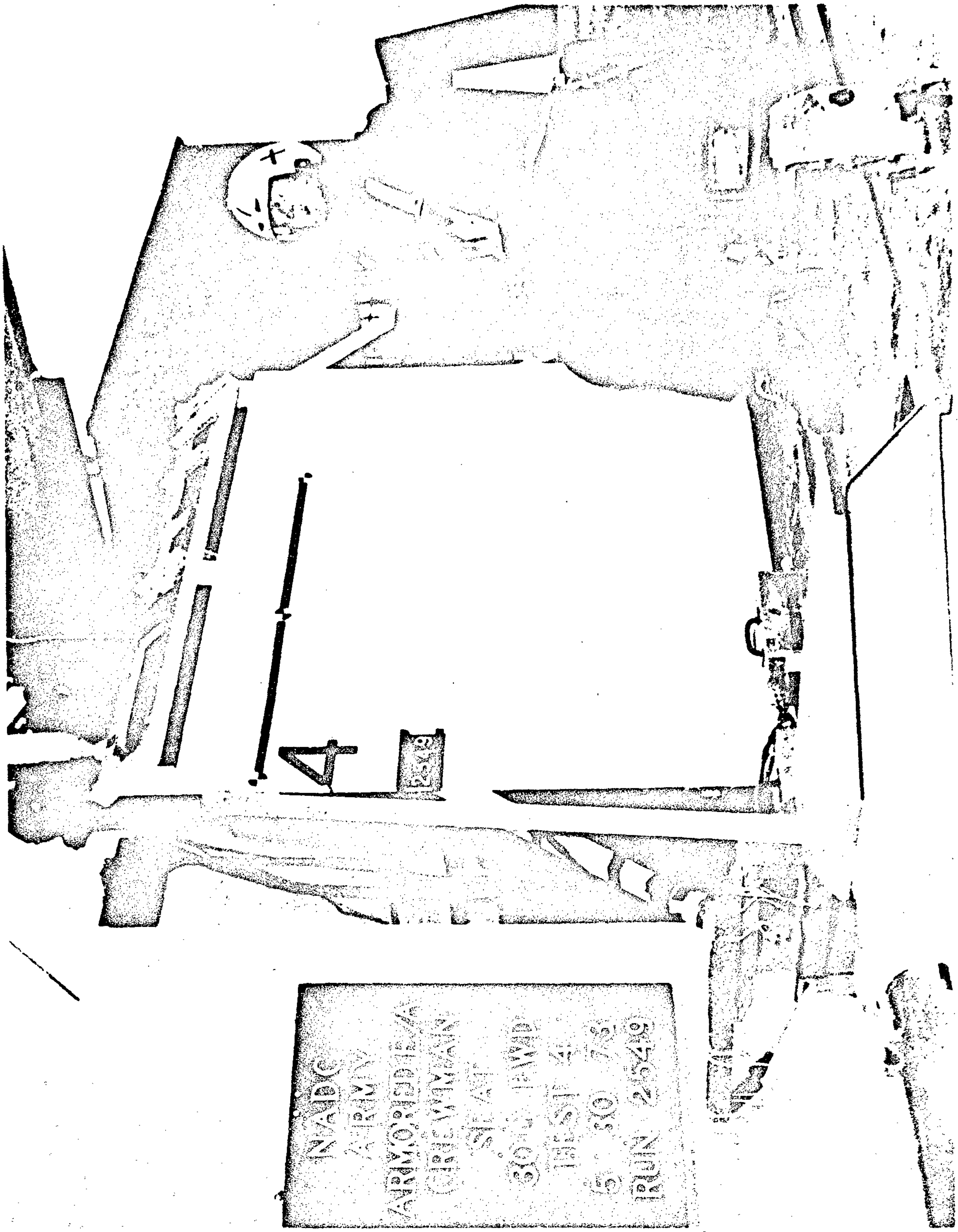


Figure 27. Forward Sled Test Configuration
Prior to Impact

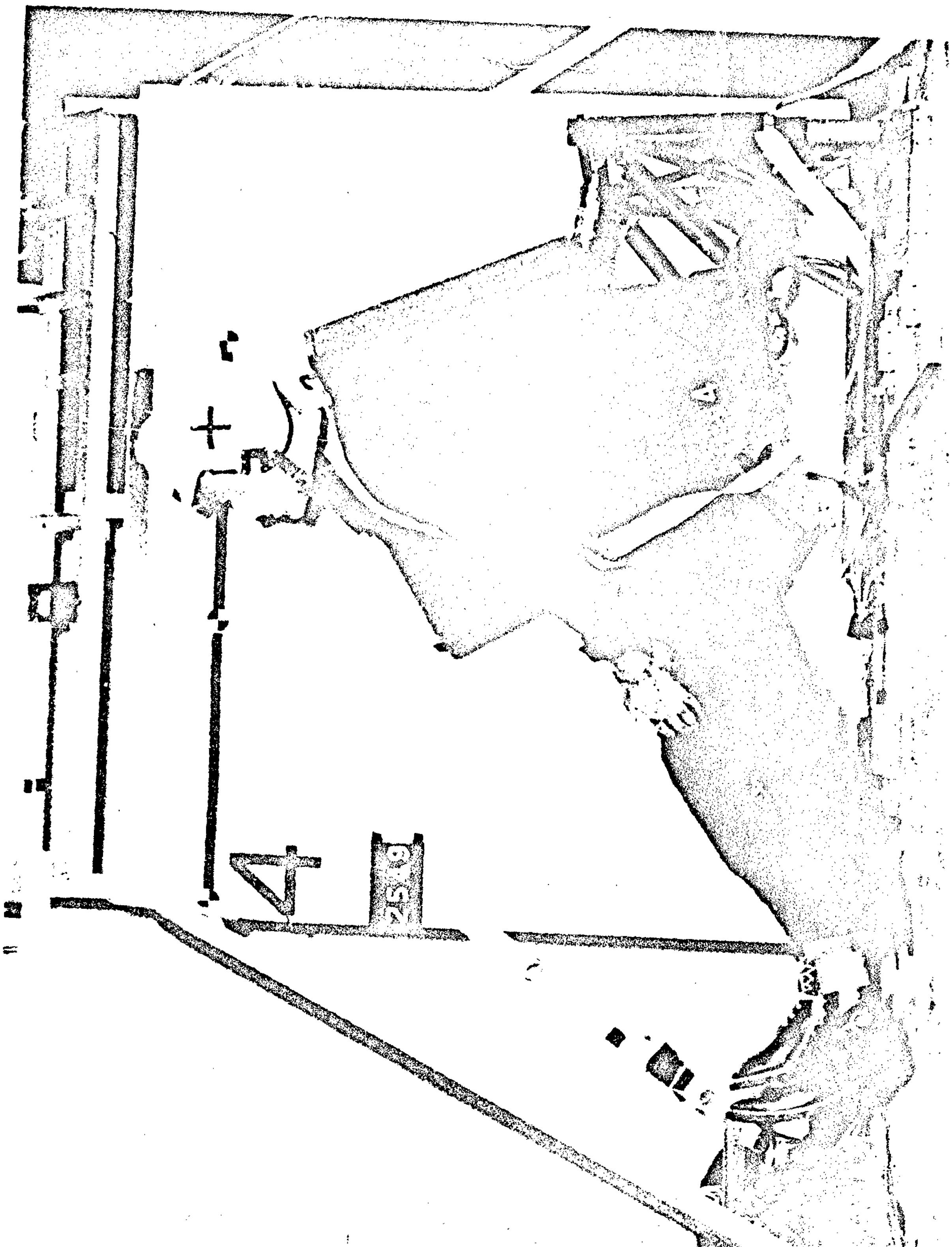


Figure 28. Forward Sled Test Configuration After Impact

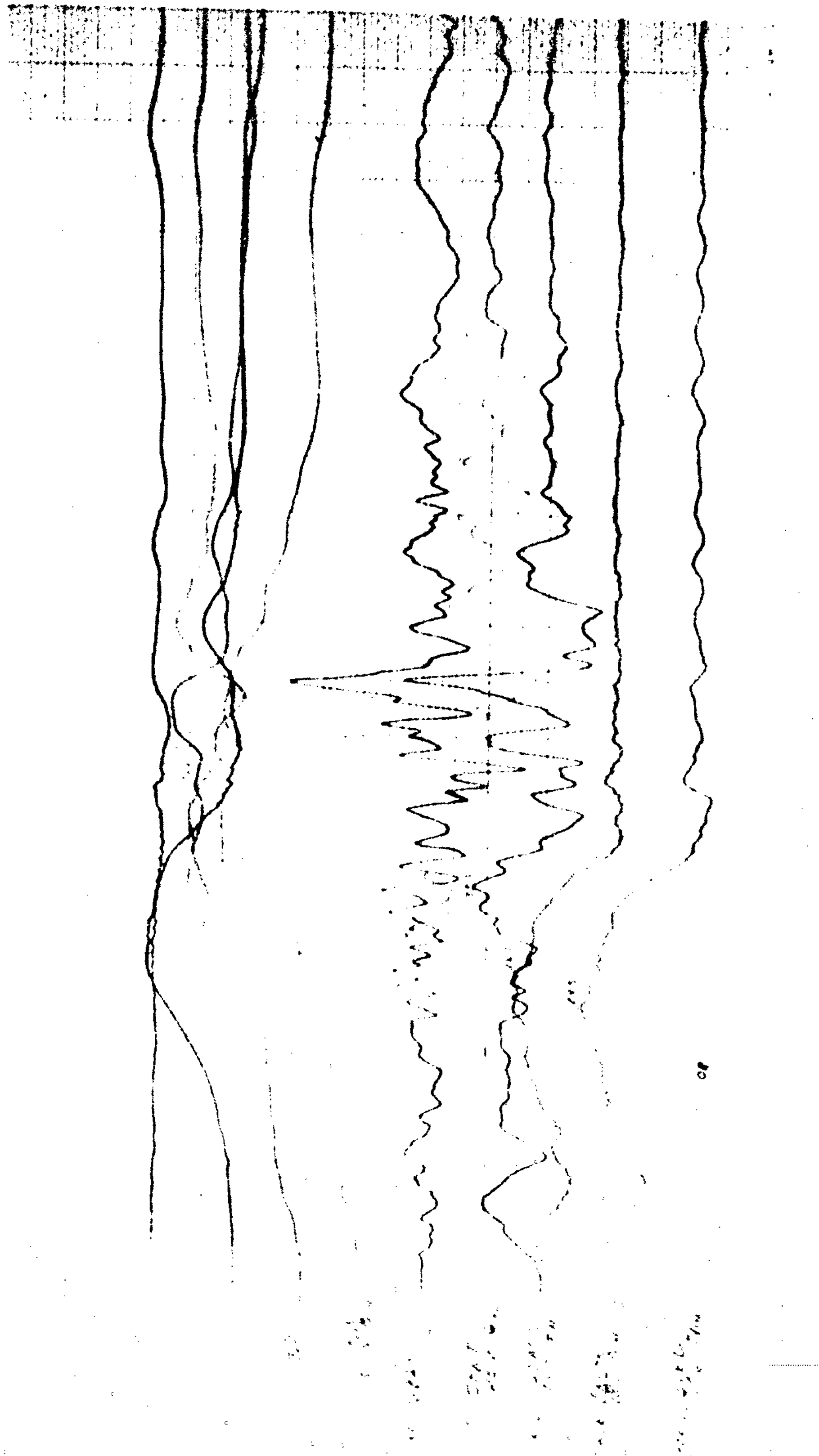


Figure 29. Forward Sled Test

vertical stroking. Aside from the obvious failures in Tests 1, 2, 3 and 3A, it was expected that the front corner of the bucket would contact the deck during the combined angle vertical drop test. Past experience has shown that the combination of pitch and roll would cause an asymmetrical loading on the system resulting in the unequal stroking of the E/A's forcing the front side edge of the seat to tip downward and sideward. Most of the input energy was dissipated during the movement of the seat and it had little differential velocity in relation to the deck when it made contact. For those tests where the seat contacted the deck the traces indicate a short duration spike with an "overshoot" acceleration. In all cases where it was concluded that the seat performed satisfactorily, there was little damage to the underside of the bucket. Contact of the seat front edge with the deck occurred during Test 3B because of the partial failure of the track. As noted previously, the track failure was attributable to the use of improper tiedown nuts and bolts."

"Throughout the test program the side armor panels were retained on the seat. Although the moveable panel was released from its upper guide bracket in tests 1A, 2, 3, 3B and 4, restraint was still provided by the panel mount and spring-loaded adjustment pin. The GFE seat cushions identical to those presently being used in the Army UH-1 helicopter armored crewman seat, were used during all testing. The one piece cushion is constructed from aluminum tubing welded together to form a frame. Raschel netting is used as the crewman support surface. Inspection of the frame after each test revealed evidence that the dummy's coccyx contacted a portion of the tubing after the netting supports failed. A two piece cushion has been proposed as a substitute for the GFE cushion. It is constructed from sheet aluminum bent into seat and back support forms and is covered with Raschel netting."

Measured vertical seat accelerations for the drop tower tests indicate only marginal compliance with the criteria of MIL-S-58095 (AV). Figure 12 of MIL-S-58095 (AV) requires the limitation of vertical seat accelerations to 23 G or less for all durations in excess of .0058 seconds. The longer durations at the 23 G level for Tests 1A and 2A were apparently caused by the "stop" rings in the upper TOR-SHOKs. Although the new TOR-SHOKs result in higher seat accelerations at the end of the seat displacement, they also provide a more controlled deceleration of the seat since the bucket is always supported, even in the event of 100% utilization of available stroke. Strain gages placed on the TOR-SHOKs to aid in evaluation of seat system performance gave force readings which were generally much higher than the preset forces specified in the design. Since deformation of the TOR-SHOK cylinders was evident in some cases (oil-canning of the TOR-SHOK end cap, etc.), the force gages will give higher readings than actual due to the occurrence of some plastic deformation of the TOR-SHOK tubing.

Some additional comments on the performance characteristics of the crashworthy seat appear warranted. It should be noted that the upper or top TOR-SHOKs do not stroke but rotate during the initial vertical displacement of the bucket. Consequently during this period of time the vertical deceleration of the bucket, as shown in Figure 17, is well within the tolerance level specified by MIL-S-58095 (AV). However since <u>all</u> the energy must be absorbed within 8 inches of vertical displacement, the upper TOR-SHOKs after rotation to the horizontal position has been completed, then start to stroke, which provides for an additional component to the bucket vertical deceleration. As the bucket moves further vertically, the upper TOR-SHOKs have rotated to an almost vertical position (which contributes even further to the bucket vertical deceleration) and in addition, due to their small stroking capacity, start to slide the helical wire

elements which further increases the force level in the upper TOR-SHOKs. These two combined effects cause the "bottoming out" effect shown in the vertical seat pan deceleration curve of Figure 17 (first curve). The increase in the force level of the top TOR-SHOKs when the wire is sliding is shown in Figure 18. Also shown in this figure is the relative constant values of the middle TOR-SHOKs which do not experience any appreciable wire sliding. For this impact condition, the bottom TOR-SHOKs do not experience any appreciable stroking and consequently were not instrumented. The bottom TOR-SHOKs do stroke when large lateral accelerations are experienced by the seat pan.

In order to insure a soft "bottoming out" condition of the seat pan in the vertical direction, the support rings in the upper or top TOR-SHOKs were a necessity, due to the very limited available displacement of the bucket and the length of the upper or top TOR-SHOKs. By use of the multiple force variation of the upper or top TOR-SHOKs and the rotation angle, the vertical deceleration of the seat pan can be made constant at a tolerable level for most of its travel but yet retain a soft "bottoming out" condition, as shown in the first trace of Figure 17. It should be noted that this trace represents a very severe crash condition, namely, a 95th percentile crash (50 feet per second) and the relatively large weight of a 95th percentile pilot. If either or both of these two conditions are reduced in severity, say a 50th percentile crash and a 50th percentile pilot, this soft "bottoming out" condition would not exist and the maximum seat pan decelerations would be well within the tolerable limits specified by MIL-S-58095 (AV). Based on the maximum available seat displacement of 7-1/2 to 8 inches, the present design optimizes the intent of MIL-S-58095 (AV) which specifically requires a minimum vertical seat pan displacement of 12, and not 7-1/2 to 8 inches.

Since the present ARA, Inc. design was tailored to fit existing aircraft configurations as well as using existing GFE seat components, the performance of the present seat in terms of tolerable vertical decelerations appears to be optimized.

The vertical dummy decelerations are largely dictated by not only the vertical seat pan decelerations but in addition, by the elasticity in the restraint system. Unfortunately the dummy experiences no vertical deceleration until half of the impulse deceleration duration was been experienced (See Figure 17, fourth curve). This characteristic means that the elasticity of the restraint system provides no restraint initially, but then the restraint system "catches up" with the dummy, resulting in high vertical deceleration loads. This situation can be alleviated by relocating the inertia reel to the top of the armored bucket (which reduces the length of shoulder harness webbing and consequently the stretch of the webbing), as well as by reducing the stretch of the shoulder harness restraint by stiffer and/or wider webbing. When these modifications are made in the restraint system, further improvements in the dummy vertical deceleration will be obtained.

Comparison of restraint effectiveness with an aluminum faced bucket using aluminum oxide tile, in comparison to the epoxy fiberglass backed boron-carbide bucket tested in Reference 2, appears warranted. The epoxy fiberglass boron-carbide bucket was found to be extremely more flexible than the aluminum backed aluminum oxide mosaic tile GFE bucket. Even after the epoxy fiberglass bucket was reinforced with additional aluminum brackets, during a forward facing sled test conducted at the ARA, Inc. facility, the dummy moved forward in the bucket to a point where he was almost completely out of the seat. Due to the elasticity of the back of the bucket and the shoulder restraint system, the use of energy absorber alleviation was meaningless since the restraint system in the forward direction was completely inadequate. The bucket and restraint system elasticity

do not absorb energy, but merely store the energy and then release it in the form of a large rebound velocity. In order to avoid this situation the elasticity of the bucket and the shoulder restraint must be reduced. Thus the use of the aluminum backed ceramic tile bucket appears mandatory for crashworthy dynamic response. Although epoxy fiberglass ceramic tile could be used for the sides and possibly for the bottom of the bucket if adequate fastening procedures are used, the manufacturing costs of the aluminum backed bucket is considerably less than the epoxy fiberglass backed bucket, and therefore, the aluminum backed bucket should be considered as the most optimum configuration.

Obviously further improvements in cockpit design will allow for better performance in seat pan decelerations by permitting optimum vertical seat pan displacements. Improved restraint systems, their optimum location on the bucket, and stiff seat back buckets will improve the vertical deceleration response of the occupant. Thus much remains to be done; however, the present crashworthy armored fixed seat demonstrates the enormous improvement in crash survivability that can be accomplished using existing cockpit arrangements and existing, relatively inexpensive, armored buckets. This improvement can be made at a negligible weight and cost penalty over present non-crashworthy fixed seats.

IX. REFERENCES

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2. ARA, Inc., "An Armored Energy Attenuating Crewman's Seat for Rotary- and Light Fixed-Wing Aircraft", NADC Report No. 72186-CS, Naval Air Development Center, Warminster, Pennsylvania, 1972.

3. ARA, Inc., "Crew Seat Support and Energy Absorbing System for Rotary- and Light Fixed-Wing Aircraft", ARA Report No. 144, ARA, Inc., West Covina, California, 1972.

4. Renneker, D. N., "A Basic Study of Energy-Absorbing Vehicle Structures and Occupant Restraints by Mathematical Model", SAE Paper No. 670897, Proceedings of SAE Automotive Safety Dynamic Modeling Symposium, Anaheim, California, Oct. 12, 1967, pp. 45-50.

5. Carr, R. W. and N. S. Phillips, "Definition of Design Criteria for Energy Absorbing Systems", NADC-AC-7010, Naval Air Development Center, Johnsville, Warminster, Pennsylvania, June 1970.

APPENDIX A

STRESS ANALYSIS OF SEAT FRAME COMPONENTS

DIAGONAL BRACE
(DWG. NO. 2300)

MAT'L: 4130 STL. H.T. $F_{tu} = 180$ KSI

COMPRESSION AND BUCKLING

LOAD: $P = 9,400$ LBS

SECTION. 1.00" O.D. × .035 WALL

$A = .106\ IN^2$

$I = .0124\ IN^4$

LENGTH: $L = 12.1^{IN}$

STRESS: $f_c = \frac{9,400}{.106} = 88,600$ psi

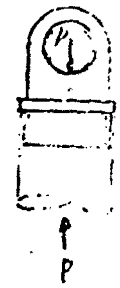
SAFETY FACTOR: $SF = \frac{F_{cy}}{f_c} = \frac{173,000}{88,600} = 2.0$

BUCKLING:

$$P_{cr} = \frac{\pi^2 E I}{L^2} = \frac{\pi^2 (3\times10^7)(.0124)}{(12.1)^2} = 25,000 \text{ LBS}$$

SAFETY FACTOR: $SF = \frac{25,000}{9,400} = 2.6$

PLUG, BRACE, DIAGONAL TUBE
(DWG. NO. 2301)



MAT'L: 4130 STL, H.T. F_{tu} = 180 KSI

COMPRESSIVE BEARING

LOAD: $P = 9,400$ LBS

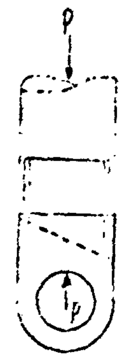
SECTION: $A_{br} = .438 \times .25 = .11$ IN²

STRESS: $f_{br} = 9,400/.11 = 85,000$ psi

$F_{bry} = 230,000$ psi

SAFETY FACTOR: $S.F. = \dfrac{230,000}{85,000} = 2.7$

CLEVIS, DIAGONAL BRACE
(DWG. NO. 2283)



MAT'L 4130 STL, H.T. F_{tu} = 180 KSI

COMPRESSIVE BEARING

LOAD: $P = 9,400$ LBS

SECTION: $A_{br} = (1.438 - 1.040)(.50) = .20$ IN²

STRESS: $f_{br} = 9,400/.20 = 47,000$ psi

$F_{bry} = 230,000$ psi

SAFETY FACTOR: $S.F. = \dfrac{230,000}{47,000} = 4.9$

VERTICAL COLUMN
(DWG. NO. 2286)
MAT'L · 4130 STL, H.T. $F_{tu} = 180$ ksi

BENDING AT THE LOWER COLLAR

LOADING. MAX. BENDING MOMENT = 27,200 IN-LBS

SECTION: 1.75 O.D. × .120 WALL

$$AREA = \frac{\pi}{4}(1.75^2 - 1.51^2) = .62 \text{ IN}^2$$

$$I = \frac{\pi}{64}(1.75^4 - 1.51^4) - (.266)(.120)(.815)^2 = .185 \text{ IN}^4$$

$$Z = \frac{I}{C} = \frac{2I}{D_o} = \frac{2(.190)}{1.75} = .212 \text{ IN}^3$$

STRESS $f_b = \frac{M}{Z} = \frac{27,200}{.212} = 128,000$ psi

SAFETY FACTOR: $S.F. = \frac{163,000}{125,000} = 1.27$ #

TENSION AT LOWER END WELDING:

LOAD. $P_v = 7,700$ LB'S

SECTION: $A_t = \pi D t = \pi(1.70)(.10) = .530 \text{ IN}^2$

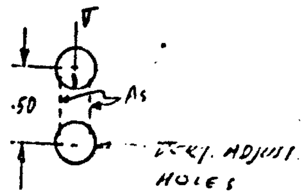
STRESS $f_t = \frac{7,700}{.530} = 14,500$ psi

USE $F_{ty} = 105\left(\frac{75}{95}\right) = 83$ ksi FOR WELDING
(MIL-HDBK-5 ...)

SAFETY FACTOR: $S.F. = \frac{83,000}{14,500} = 5.7$ #

VERTICAL COLUMN (CONT.)

SHEAR STRESS AT VERT. ADJUST HOLES



MAX. FORCE : $V = 270^{LBS} \times 22g/2 = 2{,}970$ LBS

SECTION $A_s = 2[(.50 - .266)(.120)] = .0563$ IN^2

STRESS $f_s = \dfrac{2970}{A_s} = 53{,}000$ psi

SAFETY FACTOR: $S.F. = \dfrac{F_{sy}}{f_s} = \dfrac{97.700}{53{,}000} = 1.84$

BEARING STRESS AT THE HOLES :

SECTION. $A_{br} = (.250)(.120 - .037) = .0208$

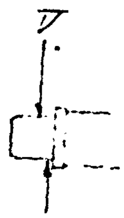
$f_{br} = \dfrac{V}{A_{br}} = \dfrac{2970}{.0208} = 143.000$ psi

SAFETY FACTOR: $S.F. = \dfrac{F_{bry}}{f_{br}} = \dfrac{230{,}000}{143{,}000} = 1.61$

PIN, LOCKING, VERTICAL
(DWG NO 2295)

MAT'L: 4130 STL, H.T. F_{tu} = 180 ksi

SHEAR STRESS



LOAD. $V = 270 \text{ lbs} \times 22g/2 = 2970 \text{ lbs}$

SECTION. $\frac{1}{4}$ DIA

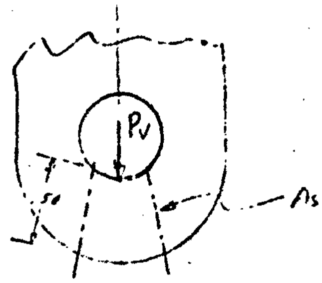
$A_s = .049 \text{ in}^2$

STRESS: $f_s = \dfrac{V}{A_s} = \dfrac{2970}{.049} = 60{,}600 \text{ psi}$

SAFETY FACTOR: $S.F. = \dfrac{F_{sy}}{f_s} = \dfrac{97{,}700}{60{,}600} = \underline{1.61}$

CLEVIS, VERTICAL COL.
(DWG NO. 2282)

MAT'L · 4130 STL, H.T. F_{tu} = 180 KSI



SHEAR STRESS OF CLEVIS

LOAD: $P_V = 7{,}700$ LBS

SECTION: $A_s \doteq 2\,(.50)(.20) = .20$

$$f_s = \frac{P_V}{A_s} = \frac{7700}{.20} = 38{,}500 \text{ psi}$$

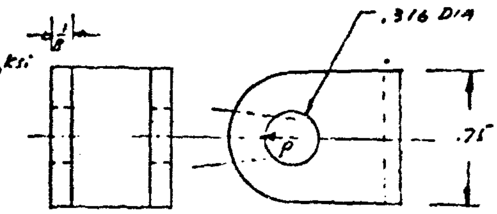
SAFETY FACTOR: $S.F. = \frac{F_{sy}}{f_s} = \frac{97{,}700}{38{,}500} = 2.54$

.874
.107

CLEVIS JOINT, TOR-SHOK

(DWG. NO. 2292, 2288)

MAT'L: 4130 STL, H.T. $F_{tu} = 180^{ksi}$



SHEAR STRESS

LOAD $P = 3{,}000$ LBS

SECTION: $A_s = 2\left(\frac{1}{8} \cdot (.75 - .316)\right) = .108$

STRESS: $f_s = \frac{P}{A_s} = \frac{3{,}000}{.108} = 27{,}800$ psi

$F_{sy} = 97{,}700$ psi

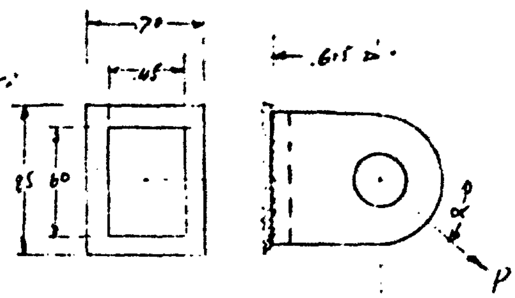
SAFETY FACTOR: $S.F. = \frac{F_{sy}}{f_s} = \frac{97{,}700}{27{,}800} = 3.5$

WELDMENT, TOR-SHOK. CLEVIS JOINT
(DWG. 2292, 2288)

MAT'L: 4130 STL, WELDING
AFT. H.T. TO $F_{tu} = 180$ ksi

$F_{tu} = 72$ ksi, $F_{ty} = 57$ ksi

$F_{su} = 43$ ksi $F_{sy} = 34$ ksi



LOAD: $P = 3{,}000$ LBS

$\alpha = 0° \sim 90°$

SECTION: $A = .70 \times .85 - .60 \times .45 = .325 \ IN^2$

$I = \frac{1}{12}\left(.70(.85)^3 - .45(.60)^3\right) = .0277 \ IN^4$

$Z = \frac{I}{C} = \frac{.0277}{.425} = .0653 \ IN^3$

STRESS & SAFETY FACTOR

(I) $\alpha = 0$

$$f_t = \frac{P}{A} = \frac{3{,}000}{.325} = 9{,}250 \ psi$$

$$S.F = \frac{57{,}000}{9{,}250} = 6.15$$

(II) $\alpha = 45°$

$$f_t = \frac{P\cos\alpha}{A} + \frac{P\sin\alpha\,(.615)}{Z} = 6{,}550 + 20{,}300 = 26{,}850 \ psi$$

$$f_s = \frac{P\sin\alpha}{A} = 6{,}550 \ psi$$

$$f_{t(max)} = \frac{f_t}{2} + \sqrt{\left(\frac{f_t}{2}\right)^2 + f_s^2} = 27{,}400 \ psi$$

$$S.F = \frac{57{,}000}{} = 2.1$$

WELDMENT, TCR-SHOCK CLEVIS JOINT (CONT)

STRESS & SAFETY FACTOR

(II) $f_{s(max)} = \sqrt{\left(\frac{f_t}{2}\right)^2 + f_s^2} = 13.900$ psi

$$S.F. = \frac{F_{sy}}{f_s} = \frac{34{,}000}{13.900} = \underline{2.45}$$

(III) $\alpha = 90°$

$$f_t = \frac{P(.625)}{Z} = \frac{3000\,(.625)}{(.0653)} = 28.700 \text{ psi}$$

$$f_s = \frac{P}{A} = 9.250 \text{ psi}$$

$$f_{n(max)} = \frac{f_t}{2} + \sqrt{\left(\frac{f_t}{2}\right)^2 + f_s^2} = 14.400 + 17.100 = 31.500 \text{ psi}$$

$$S.F = \frac{57.000}{31.500} = \underline{1.8}$$

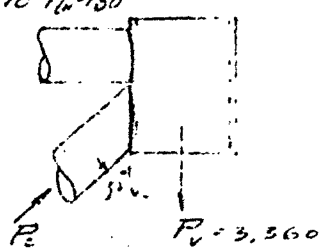
$$f_{s(max)} = 17.100 \text{ psi}$$

$$S.F = \frac{34{,}000}{17{,}100} = \underline{1.98}$$

TUBE, SUPPORT, BACK FRAME
(DWG. NO 2297, 2287)

MAT'L   4130 STL, WELDING AFT H.T TO $F_{tu} = 180^{ksi}$

COMPRESSION ON DIAGONAL MEMBER



LOAD: $P_v = 3{,}360$ LBS (FROM UPPER TWO TOR-SHOKS)

$$P_c = \frac{P_v}{\cos 52°} = 5{,}460 \text{ LBS}$$

SECTION $\frac{3}{4}$ OD × .035 WALL $L = 18$ IN

$A = .0786$ IN²

$I = .0030$ IN⁴

STRESS: $f_c = \frac{P_c}{A} = \frac{5{,}460}{.0786} = 69{,}500$ psi

STRENGTH OF WELDED SECTION $F_{cy} = 90 ksi \left(\frac{75}{95}\right) = 71.0$ ksi (MIL-HDBK-5 -8.2 11.2)

SAFETY FACTOR: $S.F. = \frac{F_{cy}}{f_c} = \frac{71.0}{69} = 1.03$

(O.K BECAUSE OF LOCAL STRESS & CURVED SECTION)

BUCKLING OF DIAGONAL MEMBER

FOR FIXED ENDS COLUMN:

$$P_{cr} = \frac{4\pi^2 EI}{L^2} = \frac{4\pi^2 (29 \times 10^6)(.0030)}{(18)^2} = 18{,}300 \text{ LBS}$$

SAFETY FACTOR $F = \frac{18{,}300}{5{,}460} = 3.34$

TUBE, SUPPORT BACK FRAME (CONT.)

SHEAR STRESS AT WELDING

LOAD: $P_V = 3.360$

WELDING AREA: $A_s \doteq \pi D t / \cos 52° = \frac{\pi(.75)(.0625)}{\cos 52°} = .239$

STRESS: $f_s = \frac{P_V}{A_s} = \frac{3.360}{.239} = 14,100$ psi

STRENGTH OF WELDING: (MIL-HDBK-5-8.2.1.1)

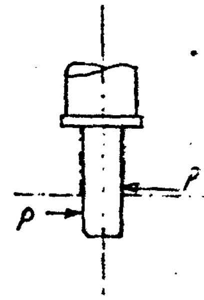
$F_{su} = 43$ ksi , $F_{sy} = 43\left(\frac{75}{95}\right) = 34$ ksi

SAFETY FACTOR: $SF = \frac{F_{sy}}{f_s} = \frac{34}{14.1} = 2.4$

LOCKING PIN, HORIZONTAL ADJUSTMENT
(DWG NO 2263, 2262)

MAT'L: 4130 STL, H.T. TO F_{tu}=180 ksi

SHEAR OF PIN



LOAD: $P = 270 \times 220/20 = 2{,}970$ LBS

SECTION $\quad DIA = .25''$

$A = \frac{\pi}{4}(.25)^2 = .049 \text{ IN}^2$

STRESS $\quad f_s = \frac{P}{A} = \frac{2{,}970}{.049} = 60{,}600$ psi

$F_{sy} = 97{,}700$ psi

SAFETY FACTOR: $S.F = \frac{97\,700}{60\,600} = 1.61$ —//—

BEARING STRESS AT RAIL

SECTION $\quad A_{br} = (.25)(.195) = .049 \text{ IN}^2$

STRESS $\quad f_{br} = \frac{P}{A_{br}} = \frac{2{,}970}{.049} = 60{,}600$ psi

$F_{bry} = 93{,}000$ psi $\quad$ (7075-T6 AL)

SAFETY FACTOR $\quad S.F = \frac{F_{bry}}{f_{br}} = \frac{93}{60.6} = 1.53$ —//—

OUTER TUBE, TOR-SHOK
(DWG. NOS 2315, 2311)

MAT'L: 4130 STL   END CAP IS WELDED TO
THE TUBE AFTER H.T.

STRESS AT WELDING JOINT

LOAD $P = 3,000$ LBS MAX

SECTION. TUBE $1\frac{1}{2}$ O.D. x .035 WALL

$A = \pi D t = .161 \text{ in}^2$

STRESS $f_t = \dfrac{5,500}{.161} = 34,200$ psi

$F_{tu} = 80,000$ psi (MIL-HDBK-5-2.2.1.1)

$F_{ty} = 80\left(\frac{75}{95}\right) = 63$ ksi

SAFETY FACTOR: $S.F. = \dfrac{63,000}{34,200} = 1.84$

BOLT, PIN JOINT, DIAGONAL BRACE

LOWER END $\frac{1}{2} \times 1\frac{1}{2}$ SHOULDER SCREW

$F_{tu} = 140{,}000$ psi (MS 51975-31)

UPPER END : $\frac{7}{16} - 14 \times 1\frac{1}{4}$ HEX HD SCREW

$F_{tu} = 150{,}000$ psi
$P_{tu} = 15{,}700$ LBS (TENSION)
$P_{su} = 60\% \, (P_{tu}) = 9{,}500$ LBS
(MS-90728-27)

$P_{sy} = 9{,}500 \text{ LBS} \left(\frac{132}{150}\right) = 8{,}350$ LBS (SINGLE SHEAR)

UPPER END JOINT IS MORE CRITICAL.

LOAD $P = 9{,}150$ LBS

SAFETY FACTOR : $S.F. = \frac{2\,(8{,}350)}{9{,}150} = 1.82$ //

BOLT
LOWER END JOINT, VERTICAL COLUMN

SECTION : $\frac{1}{2} \times 1\frac{3}{4}$ SHOULDER SCREW
(MS 51975-32)

LOAD $P = 7{,}700$ LBS

SAFETY FACTOR LESS CRITICAL THAN JOINTS AT DIAGONAL BRACE

SHOULDER SCREW, BALL JOINT

SECTION. $\frac{5}{16} \times \frac{3}{4}$, SHOULDER SCREW $\qquad A = \frac{\pi}{4}(\frac{5}{16})^2 = .077 \text{ in}^2$

MS 51975-10

$F_{tu} = 140{,}000$ psi

$F_{su} = 60\% \; F_{tu} = 84{,}000$ psi

$F_{sy} = \frac{132}{150}(84{,}000) = 74{,}000$ psi

LOAD: $P = 3{,}000$ LBS

STRESS: (DOUBLE SHEAR)

$$f_s = \frac{P}{2A} = \frac{3{,}000}{2(.077)} = 19{,}500 \text{ psi}$$

SAFETY FACTOR: $S.F = \frac{74{,}000}{19{,}500} = \underline{3.8}$ //

SCREW, ATTACHMENT BRACKET

SECTION. $\frac{1}{4}$-20 $\times \frac{1}{2}$ HEX-HD SCREW $\qquad F_{tu} = 150$ ksi

MS 90728-14

$P_{tu} = 4{,}750$ LBS

$P_{su} = 60\% \; (P_{tu}) = 2{,}700$ LBS

$P_{sy} = \frac{132}{150}(2700) = 2{,}380$ LBS (SINGLE SHEAR)

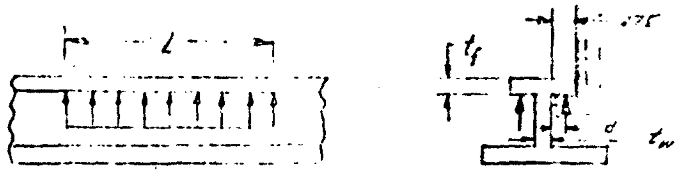
LOAD: USE $P = 3000$ LBS (AT LOWER BRACKET, EQUAL TO THE FORCE OF TOP TCR-SHOCKS)

SAFETY FACTOR. $S.F = \frac{4(2{,}380)}{3000} = \underline{3.2}$ //

B411, DWG NO 23..

MAT'L 7075 - T6 ; F_{tu} = 70 ksi

SECTION



$L = 2.8$ IN

$T_w = .20$ IN

$t_f = .20$ IN

LOAD $P = 7{,}700$ LBS

ASSUME UNIFORM DISTRIBUTION WITHIN L

& $d = 60\%(.275) = .165$ IN

STRESS & SAFETY FACTOR

TENSION OF WEB

$$f_t = \frac{P}{A_t} = \frac{7{,}700}{(2.8)(.20)} = 13{,}700 \text{ psi}$$

$$S.F. = \frac{F_{ty}}{f_t} = \frac{61{,}000}{13{,}700} = \underline{4.45}$$

BENDING & SHEAR AT FLANGE

$$f_b = \frac{M}{Z} = \frac{(\frac{P}{2})(d)}{\frac{L \cdot t_f^2}{6}} = \frac{3(7{,}700)(.165)}{(2.8)(.20)^2} = 34{,}000 \text{ LBS}$$

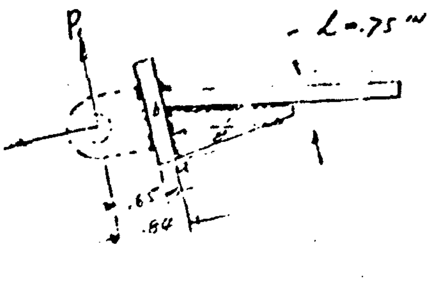
$$f_s = \frac{\frac{P}{2}}{A} = \frac{3{,}850}{(2.8)(.20)} = 6{,}900 \text{ LBS}$$

$$f_{s(max)} = \left[\left(\frac{f_b}{2}\right)^2 + f_s^2\right]^{1/2} = 18{,}300 \text{ psi}$$

$$f_{n(max)} = \frac{f_b}{2} + f_{s(max)} = 35{,}300 \text{ psi}$$

$$S.F. = \frac{F_{ty}}{f_n} = \frac{61}{35.3} = \underline{1.72}$$

SUPPOR. LOWER
(DWG. NO. 2316, 2298)



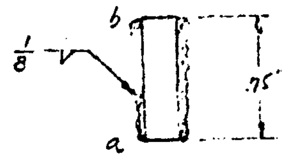
WELDMENT SECTION

Assume weldment section ab has to carry force

$P_1 = 1{,}380$ LBS OR $P_2 = 2{,}000$ LBS

$F_{tu} = 105$ ksi, $F_{ty} = 83$ ksi, $F_{su} = 65$ ksi, $F_{sy} = 50$ ksi

SECTION



$A = 2\left(\frac{1}{8}\right)(.75) = .188 \text{ in}^2$

$I_b = 2\left[\frac{1}{3}\left(\frac{1}{8}(.75)^3\right)\right] = .0352 \text{ in}^4$

$Z = .0352/0.75 = .047$

STRESS & SAFETY FACTORS

BENDING + SHEAR DUE TO P_1

$f_b = \frac{M}{Z} = \frac{(1{,}380)(.84)}{.047} = 24{,}600$ psi

$f_s = \frac{P}{A} = \frac{1{,}380}{.188} = 7{,}350$ psi

$f_{s(max)} = \left[\left(\frac{f_b}{2}\right)^2 + f_s^2\right]^{1/2} = 14{,}300$ psi $S.F. = \frac{50}{14.3} = 3.5$

$f_{t(max)} = \frac{f_b}{2} + f_{s(max)} = 26{,}600$ psi $SF = \frac{83}{26.6} = 3.1$

TENSION DUE TO P_2

$f_t = \frac{P}{A} = \frac{2{,}000}{.188} = 10{,}600$ psi $S.F. = \frac{83}{10.6} = 7.8$

MAIN SPRING
(DWG. NO 2325)

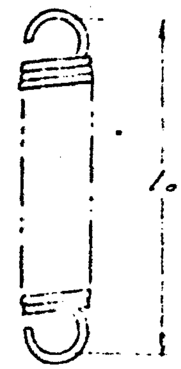
MAT'L HARD DRAWN SPRING WIRE
ASTM-A227
(F_{tu} = 200 KSI FOR .162 WIRE)

DIMENSIONS. O.D = 1.138

WIRE DIA, $d = .162$

$L_o = 11.68$ IN

NO. OF COILS $N = 62$



LOAD. INITIAL TENSION $P_o = 40$ LBS

MIN. INSTAL LENGTH. $L_{i1} = 12.25$ IN
MAX. " " $L_{i2} = 17.25$

SPRING FORCE & STRESS

SPRING RATE. $K = \dfrac{Gd^4}{8D^3N} = \dfrac{(11.5 \times 10^6)(.162)^4}{8(1.068)^3(62)} = 15$ LBS/IN

FORCE. $F_1 = 40 + 15(12.25 - 11.68) = 48.5$ LBS

$F_2 = 40 + 15(17.25 - 11.68) = 123.5$ LBS

STRESS. $f_s = K_w \dfrac{8}{\pi} \dfrac{PD}{d^3}$

$K_w = 1.1$ FOR $\dfrac{D}{d} = 6.6$

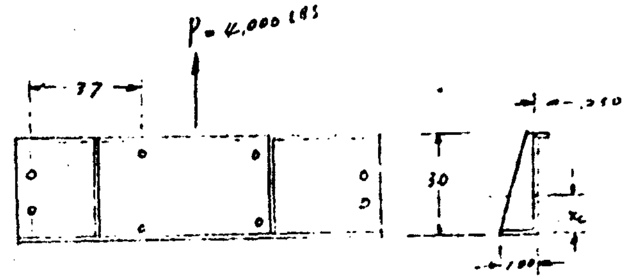
$f_s = 1.1 \dfrac{8(123.5)(1.068)}{\pi(.162)^3} = 87{,}000$ PSI

SAFETY FACTOR. $F_{sy} = 120\left(\frac{176}{200}\right) = 105$ KSI

$S.F. = \dfrac{105}{87} = \underline{1.2}_{\#}$ (O.K. BECAUSE OF FIXED DISPLACEMENT)

MOUNTING BRACKET, INERTIA REEL
(DWG NO. 2351, 2352)

MAT'L 4130 STL, H.T TO $F_{tu} = 180$ KSI
LOAD: $P = 4000$ LBS
(FORCE FROM SHOULDER HARNESS)



SECTION: .063 SHEET METAL

$x_c = 1.23$ IN

$I = .277$ IN^4

STRESS & SAFETY FACTOR

BENDING AS SIMPLY SUPPORTED BEAM & SHEAR

$M = 2000 \times 3.7 = 7{,}400$ IN-LBS

$f_b = \frac{Mc}{I} = \frac{(7400)(1.77)}{(.277)} = 47{,}300$ PSI $= f_t$

$f_s = \frac{2{,}000}{3(.063)} = 10{,}600$ PSI

$f_{s(max)} = \sqrt{(\frac{f_t}{2})^2 + f_s^2} = 26{,}000$ PSI S.F. $= \frac{97.7}{26} = 3.75$

$f_{n(max)} = \frac{f_t}{2} + f_{s(max)} = 49{,}700$ PSI S.F. $= \frac{163}{49.7} = 3.28$

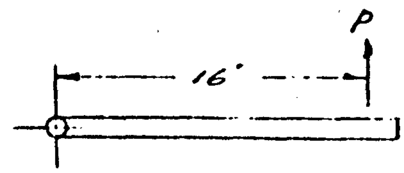
BEARING STRESS AT THE HOLES FOR BOLTS.

$A_{br} = \frac{3}{16}(.063) = .0118$ IN^2

$f_{br} = \frac{1000}{.0118} = 85{,}000$ PSI

S.F. $= \frac{F_{bru}}{f_{br}} = \frac{230{,}000}{85{,}000} = 2.7$

ARM. ACTUATOR
DWG. NO. 2256



MAT'L 4130 STL, H.T. $F_{tu} = 180$ KSI

LOAD: USE $P = 50$ LBS

SECTION 0.500 DIA × .049 WALL

$A = .0694$ IN²
$I = .0018$ IN⁴
$Z = .0071$ IN³

STRESS & SAFETY FACTOR

BENDING

$$f_b = \frac{M}{Z} = \frac{(50)(16.0)}{.0071} = 112{,}000 \text{ psi}$$

$$S.F. = \frac{F_{ty}}{f_b} = \frac{163}{112} = 1.45$$

TORSION

$$f_s = \frac{M}{2A_m t} = \frac{50 \times 16}{2\left(\frac{\pi}{4}(.451)^2\right)(.049)} = 51{,}000 \text{ psi}$$

$$S.F. = \frac{F_{sy}}{f_s} = \frac{97{,}700}{51{,}000} = 1.92$$

APPENDIX B

REPORT OF ENVIRONMENTAL TESTS ON HELICOPTER SEAT

UNIVERSAL REPORT NO.________________

ORIGINATORS REPORT NO. F-72683

REVISION________________

REPORT OF
ENVIRONMENTAL TESTS
ON
ARA, INC. HELICOPTER SEAT

TESTS PERFORMED BY Ogden Technology Laboratories, Inc.

TESTS AUTHORIZED BY ARA, Inc. Purchase Order No. 2514

CONTRACT NUMBER N62269-72-C-0657

	DATE	SIGNATURE	
Tests Initiated	12-19-72		
Tests Completed	2-23-73		
Report Written By	5-10-73	R. J. McKellgott	
Test Engineer	5-10-73	A. Hernandez	
Supervisor			
Supervisor	5-10-73	R. D. Short	
Quality Assurance	5-10-73	R. J. McKellgott	OGDEN QA
Government Rep.	5-10-73	B. M. Hamilton	
Final Release	5-9-73		

bls

REPORT SUMMARY SHEET

omponent/Parts: elicopter Seat, Seat Frame ssembly and Complete Seat ssembly	Program: Originators Report No.: F-72683
riginator's Report Title: eport of Environmental Tests	Test Completed: 2-23-73 Report Completed: 5-10-73 Test Type: Qualification

ecifications: A. MIL-S-58095 AV B. MIL-STD-810B, Notice 1

GH TEMPERATURE TEST - Seat Frame Assembly

ecifications: A. Paragraph 4.5.4.1
B. Method 501, Procedures I and II

st Conditons: I - Exposure to 160°F for 48 hours, operation at 160°F, and post-test operation at room ambient temperature.

II - Exposure to 3, 12-hour temperature cycles, 120°F for 6 hours, 154°F for four (4) hours with one (1) hour transitions; then stabilization and operation at 160°F and post-operation at room ambient.

sults: No indication of malfunction or evidence of damage.

W TEMPERATURE TEST - Seat Frame Assembly

ecifications: A. Paragraph 4.5.4.2
B. Method 502, Procedure I

st Conditions: Stabilization for 4 hours and operation at -65°F and post operation at room ambient.

sults: No indication of malfunction or evidence of damage.

IIDITY TEST - Seat Frame Assembly

cifications: A. Paragraph 4.5.4.3
B. Method 507, Procedure I

t Conditions: Exposure to 95% RH with temperature cycled from 90 to 160 to 90°F in 24 hour cycles for 10 cycles, post operation at room ambient.

ults: No evidence of damage or deterioration.

Test Report No. F-72683

REPORT SUMMARY SHEET

FUNGUS TEST - Representative Samples

Specifications: A. Paragraph 4.5.4.4
B. Method 508

Test Conditions: Exposure to 95% RH at 86°F for 28 days after innoculation with specified spore suspension.

Results: No evidence of fungus growth or attack.

SALT FOG TEST - Seat Frame Assembly

Specifications: A. Paragraph 4.5.4.5
B. Method 509

Test Condititons: Exposure to fog from a 5% solution for 48 hours at 95 °F. Post test operation.

Results: No evidence of damage or deterioration.

DUST TEST - Seat Frame Assembly

Specifications: A. Paragraph 4.5.4.6
B. Method 510

Test Conditions: Exposure to dust at 0.22 grams/ft^3 and 1740 feet/minute for 6 hours at 73°F and 6 hours at 145°F with 16 hours at 145°F, no dust, 240 feet/minute air between 6 hour exposures.

Results: No visible evidence of damage.

VIBRATION TEST - Complete Seat Assembly with anthropormorphic dummy

Specifications: A. Paragraph 4.5.4.7
B. Method 514, Procedure I, Parts 1, 2, and 3.

Test Conditions: 3 hours of vibration, resonance search, dwell and cycling in each of three (3) axes, 5 to 500 Hz maximum of ± 2.5 g.

Results: No visible evidence of damage or deformation.

SUMMARY OF REPORT

The test item completed the test program without visible evidence of physical damage or deterioration.

TABLE OF CONTENTS

NOTICES

When government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

ADMINISTRATIVE DATA

1.	PURPOSE OF TEST:	To perform Environmental Tests to determine the extent of compliance with the specifications cited below.
2.	MANUFACTURER:	ARA, Inc.
3.	DESCRIPTION OF TEST ITEM:	HELICOPTER Seat
4.	REFERENCES:	MIL-S-58095(AV) and MIL-STD-810B
5.	QUANTITY OF TEST ITEMS:	One (1) Seat Frame Assembly and one (1) Completely Assembled Seat
6.	SECURITY CLASSIFICATION:	Unclassified
7.	DATE TESTS COMPLETED:	2-23-73
8.	TESTS CONDUCTED BY:	Ogden Technology Laboratories, Inc. 1536 East Valencia Drive Fullerton, California 92631
9.	TEST ITEM DISPOSITION:	Returned to: ARA, Inc. 2017 West Garvey Avenue West Covina, Calif. 91790
10.	PURCHASE ORDER NUMBER:	2514
11.	SOURCE INSPECTION:	DCAS QAR, and OTL QA
12.	GOVERNMENT CONTRACT NO.:	N62269-72-C-0657

FACTUAL DATA

1.0 DESCRIPTION OF TEST APPARATUS

1.1 All quantitative test measurements were made with certified accurate instruments in current calibration, and all instruments used had a valid calibration sticker attached. All instruments were calibrated in accordance with MIL-C-45662A and MIL-Q-9858A. A list of the test apparatus follows:

1.2 HIGH TEMPERATURE TEST

Leatherman High Temperature Chamber, Controlled by Honeywell S/N 935809, -100 to +200°F; calibrated at 6 month intervals due 1-20-73. OTL Control No. 5009

1.3 LOW TEMPERATURE TEST

Conrad High-Low Temperature Chamber, controlled by Honeywell, S/N 948196, -125 to +325°F, 1% accuracy; calibrated at 6 month intervals due 2-15-73. OTL Control No. 453

1.4 HUMIDITY TEST

Fielden Humidity Chamber, controlled by Honeywell, S/N 954704, 0 to 200°F, 1% accuracy; calibrated at 6 month intervals due 2-22-73. OTL Control No. 5275

1.5 FUNGUS TEST

Leatherman Fungus Chamber, 3' x 3' x 3', 0 to 200°F, 1% accuracy controlled by Honeywell, S/N 844905, calibrated at 6 month intervals due 5-9-73. OTL Control No. 5006

1.6 SALT FOG TEST

Industrial Filter Salt Spray Chamber, Model 411-1C, S/N 53736, +1% accuracy, ambient to +140°F, calibrated at 6 month intervals due 1-16-73. OTL Control No. 1853

Sargent Specific Gravity Scale, 1.000 to 1.070; calibration Not Required. OTL Control No. 67108

LaMotte Chemical Co. Colormatic Comparator, By-Color Reader, Calibrated by Manufacturer. OTL Control No. E-2701-5

FACTUAL DATA

1.7 DUST TEST

Leatherman Sand and Dust Chamber, 2' x 2' x 2', 0-200°F, 1% accuracy, 9% RH, controlled by Honeywell, S/N 535807; calibrated at 6 month intervals due 4-11-73. OTL Control No. 5008

1.8 VIBRATION TEST

Feldmar Stop Watch, Model 601; calibrated at 12 month intervals due 9-14-73. OTL Control No. 3021

Bruel & Kjaer Automatic Exciter Control, Model 1025; calibrated at 6 month intervals due 7-26-73. OTL Control No. 1495

Endevco Accelerometer, Model 2242; calibrated at 6 month intervals due 7-10-73. OTL Control No. 2673

Unholtz-Dickie Amplifier, Model 8 PMCV; calibrated at 6 month intervals due 3-19-73. OTL Control No. 585

Endevco Accelerometer, Model 2245; calibrated at 6 month intervals due 3-16-73. OTL Control No. 2135

Unholtz-Dickie Amplifier, Model 8 PMC; calibrated at 6 month intervals due 2-24-73. OTL Control No. 1162

Honeywell X-Y Recorder, Model 320; calibrated at 6 month intervals due 3-1-73. OTL Control No. 3208

Moseley Log Converter, Model 60D; calibrated at 6 month intervals due 3-14-73. OTL Control No. 3220

MB Power Amplifier, Model 5140; calibration Not Required

MB Vibration Exciter, Model C-210; calibration Not Required

FACTUAL DATA

2.0 TEST PROCEDURES

2.1 GENERAL

2.1.1 The tests were conducted in strict accordance with MIL-STD-810B as outlined in MIL-S-58095, Paragraph 4.5.4.1 through 4.5.4.7. The following discussion is to provide details of the testing and to assist in the interpretation of the test data.

2.1.2 Only the Seat Frame Assembly was subjected to the Temperature, Humidity, Salt Fog and Dust Tests. The complete Seat Assembly was subjected to the Vibration Test. Representative samples were subjected to the Fungus Test.

2.2 HIGH TEMPERATURE TEST (Method 501 of MIL-STD-810B)

2.2.1 Procedure I - The test item was installed in the test chamber as shown in Photograph No. 1 and exposed to a temperature of 160°F for 48 hours.

At the conclusion of the test the unit was operated at 160°F, the lever was actuated and the spring loading was reset. The operation was repeated after the unit was returned to room ambient temperature.

2.2.2 Procedure II - The test chamber was programmed for the following temperature cycle:

a. 6 hours at 120°F

b. 120°F to 154°F in one (1) hour

c. 154°F maintained for 4 hours

d. 154°F to 120°F in one (1) hour

The test item was subjected to three (3) consecutive programmed cycles. At the conclusion of the test the unit was operated at 120°F and again at room ambient temperature.

2.3 LOW TEMPERATURE TEST (Method 502, Procedure I)

2.3.1 The test item was installed in a test chamber and subjected to a temperature of -65°F until the unit was completely stabilized, approximately four (4) hours.

2.3.2 Following stabilization the unit was operated at the low temperature.

FACTUAL DATA

2.3.3 The test item was then stabilized at room ambient temperature and operated.

2.4 HUMIDITY TEST (Method 507, Procedure I)

2.4.1 The test chamber was programmed for the following temperature cycle with the relative humidity maintained at 95±5 %:

a. Room ambient to 160°F in 2 hours

b. 160°F maintained for 6 hours

c. 160°F gradually to room ambient (68 to 100°F)

2.4.2 The test item was installed in the test chamber and subjected to 10 continuous and consecutive programmed cycles.

2.4.3 At the conclusion of the test the test item was operated and inspected for evidence of corrosion or deterioration.

2.5 FUNGUS TEST (Method 508)

Representative samples of the Seat Materials were sprayed with fungus spores and incubated for 28 days. The spore suspension was prepared, the units were innoculated and inspections were performed by a Ph. D. Mycologist.

2.6 SALT FOG TEST (Method 509)

2.6.1 The test item was installed in the salt spray test chamber and subjected to a wet, dense, salt fog from a 5% solution for 48 hours, additional information was as follows:

Type of Salt:	Mortons 999 (99.998 NaCl)
Type of Water:	Distilled
pH of Solution:	6.8
S.G. of Solution:	1.040
Chamber Temperature:	Maintained at +95°F

2.6.2 At the conclusion of the exposure the test item was removed from the chamber, salt deposits were washed off with tap water and the test item was visually examined for deterioration or corrosion. The test item was then subjected to a Operation Test.

FACTUAL DATA

2.7 DUST TEST (Method 510)

2.7.1 The test item was installed in the test chamber as shown in Photograph No. 2.

2.7.2 The test chamber was programmed for the following conditions:

Dust Density	- 0.22 grams per cubic foot
Air Velocity	- 1740 feet per minute
Temperature	- 73°F
Relative Humidity	- Less than 22%

The test item was exposed to these conditions for 6 hours.

2.7.3 The chamber was then programmed for the following:

Dust Density	- None, dust turned off
Air Velocity	- 240 feet per minute
Temperature	- 145°F
Relative Humidity	- Less than 10%

These conditions were maintained for 16 hours.

2.7.4 The conditions of paragraph 2.7.2 were then imposed on the test item for six (6) hours except that the temperature was maintained at 145°F.

2.7.5 At the conclusion of the test, the test item was removed from the chamber. Dust deposits were brushed off, and the test item was visually examined for damage. The test item was then operated.

2.7.6 Following the Dust Test, the Seat Frame Assembly was returned to A ARA, Inc. for assembly with the Seat for the Vibration Test.

2.8 VIBRATION TEST (Method 514.1, Procedure I, Part 1)

2.8.1 Installation

The Seat Assembly, with an anthropomorphic dummy installed, was mounted on the head of the vibrator, as shown in Photograph No. 3, for vertical axis vibration.

The assembly was mounted on Team Tables for vibration in the other two (2) axes as illustrated in Photograph No. 4.

2.8.2 Instrumentation

The control accelerometer was mounted on the test fixture. A monitor accelerometer was mounted on the bottom of the seat. Both accelerometers were maintained in the axis of vibration. The outputs were recorded on an X-Y recorder as indicated below.

FACTUAL DATA

2.8.3 **Vibration**

The Seat Assembly was subjected to three (3) hours of vibration in each of three (3) orthogonal axes. Testing consisted of a resonance search, dwell vibration at resonance (as applicable), and cycling vibration at the following levels:

(Curve M, Figure 514.1-3, reduced 50%).

Frequency Range (Hz)	Levels
5 - 20	0.1 inch da
20 - 33	± 2 g
33 - 500	± 2.5 g

2.8.4 A summary of the testing follows:

Axis	Test Description	Duration (Minutes)	Recorded
Vertical	Resonance Search & Cycling 5 - 500 - 5Hz	60	Control and Response
	Dwell at 29 Hz	30	- - - - - -
	Dwell at 34 Hz	30	- - - - - -
	Dwell at 50 Hz	30	- - - - - -
	Dwell at 435 Hz	30	- - - - - -
Front to Back	Resonance Search	15	Control and Response
	Dwell at 43 Hz	30	- - - - - -
	Cycling 5-500-5 Hz	135	Response, 1 Cycle
Side to Side	Resonance Search	15	Control and Response
	Cycling 5-500-5 Hz	165	None

2.8.5 At the conclusion of the tests in each axis, the test item was visually examined for damage.

2.8.6 At the conclusion of the test, the test item was returned to ARA, Inc. for final evaluation.

NOTE: Rods were installed on the test item at the beginning of the testing. These rods were not a part of the test item, but were installed for information purposes by ARA, Inc.

FACTUAL DATA

3.0 RESULTS OF TESTS

3.1 GENERAL

The test item completed the test program without visible evidence of physical damage or deterioration.

3.2 HIGH TEMPERATURE

There was no visible evidence of damage resulting from the exposure, and operation was normal at 160°F, 120°F, and at room ambient temperatute following the tests.

3.3 LOW TEMPERATURE

The test item operated normally at -65°F and at room ambient following the test. There was no visible evidence of deterioration noted.

3.4 HUMIDITY TEST

There was no visible evidence of corrosion or deterioration, and the test item operated normally, at the conclusion of the test.

3.5 FUNGUS TEST

The three (3) test samples showed no evidence of fungus growth.

3.6 SALT FOG TEST

There was no evidence of corrosion or deterioration, and the test item operated normally at the conclusion of the test.

3.7 DUST TEST

There was no visible evidence of damage, and operation was normal at the conclusion of the test.

3.8 VIBRATION TEST

There was no visible evidence of physical damage resulting from the vibration.

FACTUAL DATA

4.0 TEST DATA

4.1 GENERAL

All information recorded on data sheets is reproduced in this section in the following order:

4.2 HIGH TEMPERATURE TEST

One (1) exposure data sheet for Procedure I and one (1) for Procedure II.

4.3 LOW TEMPERATURE

One (1) exposure data sheet.

4.4 HUMIDITY TEST

One (1) exposure data sheet and a typical 24-hour circular chart.

4.5 FUNGUS TEST

Mycological Report, one (1) page.

4.6 SALT FOG TEST

One (1) exposure data sheet.

4.7 DUST TEST

One (1) exposure data sheet.

4.8 VIBRATION TEST

One (1) exposure data sheet, a sketch showing test axes designations, and 10 X-Y recordings are presented.

4.9 PHOTOGRAPHS

Photographs are reproduced at the end of this section, as follows:

No. 1 - Typical Test Chamber Installation
No. 2 - Dust Test Setup

FACTUAL DATA

4.9 PHOTOGRAPHS (Continued)

No. 3 - Vertical Axis Vibration Test Setup
No. 4 - Typical Horizontal Axis Test Setup

4.10 TEMPERATURE CHARTS

Temperature charts will be retained on file at OTL, File No. F-72683, and can be made available to authorized persons on request.

Date Started: 12-19-72	TEST DATA	Performed By: [illegible]ZEN
Date Completed: 12-21-72	Specimen Description: SEAT ASSY	OTL Q.A. OGDEN QA-2
Temp. SEE Below / Humidity <15%	Test: High TEMPERATURE	Cust. Insp.
F72683	Customer: A.R.A. INC	Gov't. Insp.
P.O. 2574-	MIL-STD 810B PROC. 1	

DATE	TIME	TEMP		
12-19	1415	–		INSTALLED TEST ITEMS IN ChAMBER.
	1445	160		CONDITIONS MET
	1800	160		ChAMBER ChECK
	2200	160		" "
12-20	0200	160		" "
	0600	160		" "
	1000	160		" "
	1400	160		" "
	1800	160		" "
	2200	160		" "
12-21	0200	160		" "
	0600	160		" "
	1000	160		" "
	1445	160		END PROCEDURE 1 PREPAIR FOR PROC. #2
	1300	120		START PROCEDURE NO 2
	1600	120		ChAMBER ChECK
	1900	120		INCREASE TEMP TO +154°F
	2000	154		CONDITIONS MET
	2200	154		ChAMBER ChECK
	2400	154		DECREASE TEMP TO +120°F
12-22	0100	120		END CYCLE NO 1 REPEAT CYCLE NO 1 FOR
				A TOTAL OF 3 CYCLES
	0100	120		START CYCLE NO 2
	1300	120		END CYCLE NO 2 & START CYCLE NO 3
12-23	0100	120		END CYCLE NO 3 & END TEST
				THERE WAS NO DAMAGE NOTED & ALL
			B-16	FUNCT PERFORMED NORMALLY

OGDEN TECHNOLOGY LABORATORIES, INC.

TEST DATA

Date Started: 12-21-72	Specimen Description: Helicopter Seat	Performed By: TOWNZEN
Date Completed: 12-22-72	Test: Hi-Temp	OTL Q.A. OGDEN QA-2
Temp. See Below / Humidity <15%	Customer: A.R.A.	Cust. Insp.
F-72683	MIL-STD 810B Proc 2	Gov't. Insp.
PO 2514		

DATE	TIME	TEMP °F NOTED	
1972			
12-21	0900	+120	START TEST
	1200	120	Chamber Check
	1500	120	INCREASE TEMP TO +154
	1600	154	CONDITIONS MET
	1800	154	Chamber Check
	2000	154	DECREASE TEMP TO +120°F
	2100	120	END Cycle No 1 REPEAT Cycle No 1 FOR A TOTAL OF 3 Cycles
	2100		START Cycle No 2
12-22	0900		END Cycle No 2
	0900		START Cycle No 3
	2100		END Cycle No 3 & END TEST
			THERE WAS NO VISIBLE DAMAGE DUE TO THE TEMP EXPOSURE All FUNCTIONAL TEST OPERATED PROPERLY.

Date Started: 12-29-72	TEST DATA	Performed By: Townzen
Date Completed: 12-29-72	Specimen Description: SEAT ASSY	OTL Q.A. OGDEN QA-2
Temp. SEE BELOW / Humidity N.A.	Test: LOW TEMP OPERATIONS	Cust. Insp.
F72683	Customer: A.R.A.	Gov't. Insp.

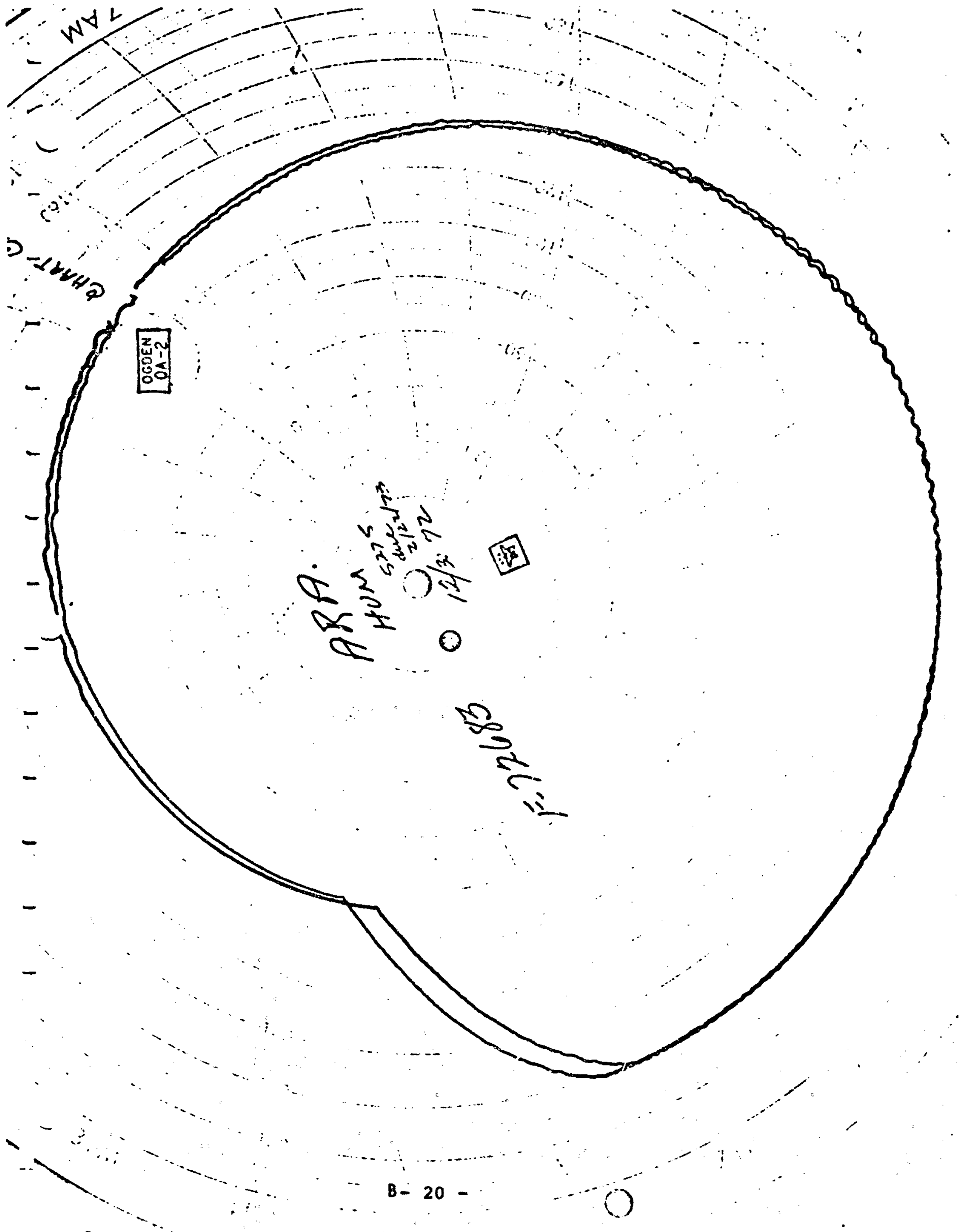
DATE	TIME	TEMP °F NOTED		
1972				
12-29	0810	–		INSTALLED TEST ITEM IN CHAMBER
				DECREASED TEMP TO -65°F
	0845	-65		CONDITIONS MET
	0915	-65		CHAMBER CHECK
	0945	-65		" "
	1015	-65		" "
	1045	-65		" "
	1115	-65		" "
	1145	-65		" "
	1215	-65		END SOAK OPERATED TEST ITEM
				10 TEN TIMES TEST ITEM OPERATED
				PROPERLY IN ALL OPERATIONS

DATE STARTED: 12-29-72	PARTS TEST DATA	TEST ENGINEER: TOWNZEN
DATE COMPLETED: 1-8-73	SPECIMEN DESCRIPTION: SEAT ASSY	GROUP LEADER: [illegible]
TEMP: NOTED	TEST: HUMIDITY TEST	K72683
HUMIDITY: NOTED	VENDOR: A.R.A.	

C. TEST RESULTS -- EXPOSURE TABLE

DATE	TIME	TA	RH	STEP	CYCLE	SAMPLE	COMMENT
	--	--	95	1-4	1-10		SPECIFIED OGDEN 04-2
12-29	1700	--	--	1	1		SAMPLES PLACED IN CHAMBER-HEAT ON
	1900	160	95	2	1		CONDITIONS MET
12-30	0100	160	95	3	1		HEAT OFF
	1700	90	--	4	1		END CYCLE 1
	1700	90	--	1-4	2		REPEAT CYCLE 1
12-31	1700	90	--	1-4	3		
1-1	1700	90	--	1-4	4		
1-2	1700	90	--	1-4	5		
1-3	1700	90	--	1-4	6		
1-4	1700	90	--	1-4	7		
1-5	1700	90	--	1-4	8		
1-6	1700	90	--	1-4	9		
1-7	1700	90	--	1-4	10		REPEAT CYCLE 1
1-8-73	1700	90	--	-	10		END CYCLE 10 AND HUMIDITY EXPOSURE

THERE WAS NO VISIBLE DAMAGE NOTED DUE TO THE HUMIDITY EXPOSURE


7 AM
OGDEN
OA-2

Frank E. Swatek, Ph.D.
Industrial & Mycological Consultant
812 STEVELY AVENUE
LONG BEACH, CALIFORNIA 90815

DATE: 1-17-73

JOB NO. F-72683

CLIENT: Ogden Technology Laboratories, Inc.

ITEM: Three (3) Helicopter Seat Parts (ARA, Inc.)

INVESTIGATION: Fungus resistance test in accordance with specification.

PROCEDURE: The unit was sprayed with a suspension of viable fungus spores in accordance with specification Mil-STD-810B.

Spores from the following fungi were used:

<u>Chaetomium</u> <u>globosum</u> ATCC 6205
<u>Aspergillus</u> <u>niger</u> NLabs 386
<u>Aspergillus</u> <u>flavus</u> NLabs 380
<u>Penicillium</u> <u>funiculosum</u> NLabs 391
<u>Aspergillus</u> <u>versicolor</u> NLabs 432

The specimen was placed in the test chamber with an internal temperature of 86 ± 4° and a relative humidity of 95% ± 5%. This is accomplished by means of a heater immersed in water within the chamber which is controlled by a thermocouple placed in the chamber atmosphere, set to regulate the ambient temperature. At the end of the 28 day period the unit was visually examined for the presence of fungus growth and/or material deterioration.

CONTROLS: After 14 days all three (3) control material show fungus growth.

RESULTS: There is no evidence of fungus growth on the external surfaces of the three (3) test specimens.

OGDEN QA-2

Test By: Frank E. Swatek Ph.D.
(signature)

OGDEN TECHNOLOGY LABORATORIES, INC.

Job Number E72683

Date 1-9-73

SALT SPRAY DATA SHEET

Page Number

Customer A.R.A.

Specimen SEAT ASSY Part No. Serial No.

Specification No. MIL-STD 810B Para. No.

Preparation of Specimen(s) N/A

Protective Coating or Covering for Non-Tested Parts

N/A

Vents, Ports, Connectors, etc. Capped: Yes No Remarks

N/A

Support Method Nylon CORD

Orientation of Specimen(s) VERT

Solution: Salt 5 % H_2O 95 % (by weight) pH of Solution 6.8

at 95 °F Specific Gravity of Solution 1.040 at 95 °F

Start date and time 1-9-73 0900 Nozzel Pressure 16

Chamber Temperature 95 °F Water Column Temperature 109 °F

TEST RECORD
(Each 24 Hours)

Elapsed Time (hours)	Collected Solution (Volume) per 80 square centimeters of Horizontal Surface Area (milliliters per hour)	Collected pH Value	Solution Specific Gravity	Chamber Temp. (°F)
24	31 ÷ 1.28	6.8	1.040	95
48	62 ÷ 1.28	6.8	1.040	95

OGDEN QA-2

Stop date and time 1-11-73 0900 Test Duration 48 hours

Interruptions (explain) Chamber Check Each Day

Results of Test No DAMAGE NOTED DUE TO THE SALT FOG EXPOSURE - OPERATION OK

Photograph taken: Yes No ✓

Test Technician [signature] Test Engineer [signature]

Inspector (Customer/Gov't)

[signature] OGDEN QA-2

Quality Assurance Manager

Job Number F-72683

Date 1-11-73

Page Number

OGDEN TECHNOLOGY LABORATORIES, INC.

SAND AND DUST DATA SHEET

Customer A.R.A.

Specimen SEAT ASSY Part No. Serial No.

Specification No. MIL-STD 810 B Para. No. 3.1

Preparation of Specimen(s) N/A

Protective Covering on Non-Tested Parts N/A

Vents, Ports, Connectors, etc. Capped: Yes No Remarks

N/A

Support Method METAL GRATE

Orientation of Specimen(s) HORIZ

Chamber Controls: Sand and Dust Density 0.3 ± 0.2 grams/cubic foot

Wind Velocity 1750 ± 250 & 300 ± 200 feet/minute

Relative Humidity < 22 & < 10 percent

Temperature 73 & 145 °F

Elapsed Time (hours)	Sand And Dust Density (grams/cu.ft.)	Air Velocity (ft/minute)	Temperature (°F)	Relative Humidity (%)
6	.22	1740	73	< 22
16		240	145	< 10
6	.22	1740	145	< 22

Remarks: NO DAMAGE NOTED DUE TO THE S&D EXPOSURE

Interruptions during test (explain): NONE

OPERATION OK.

Results: Damage or Deformation: Yes No ✓ (explain above)

Photograph taken: Yes ✓ No

Test Technician [signature] Test Engineer A. Hernandez

Inspector (Customer/Gov't)

[signature]

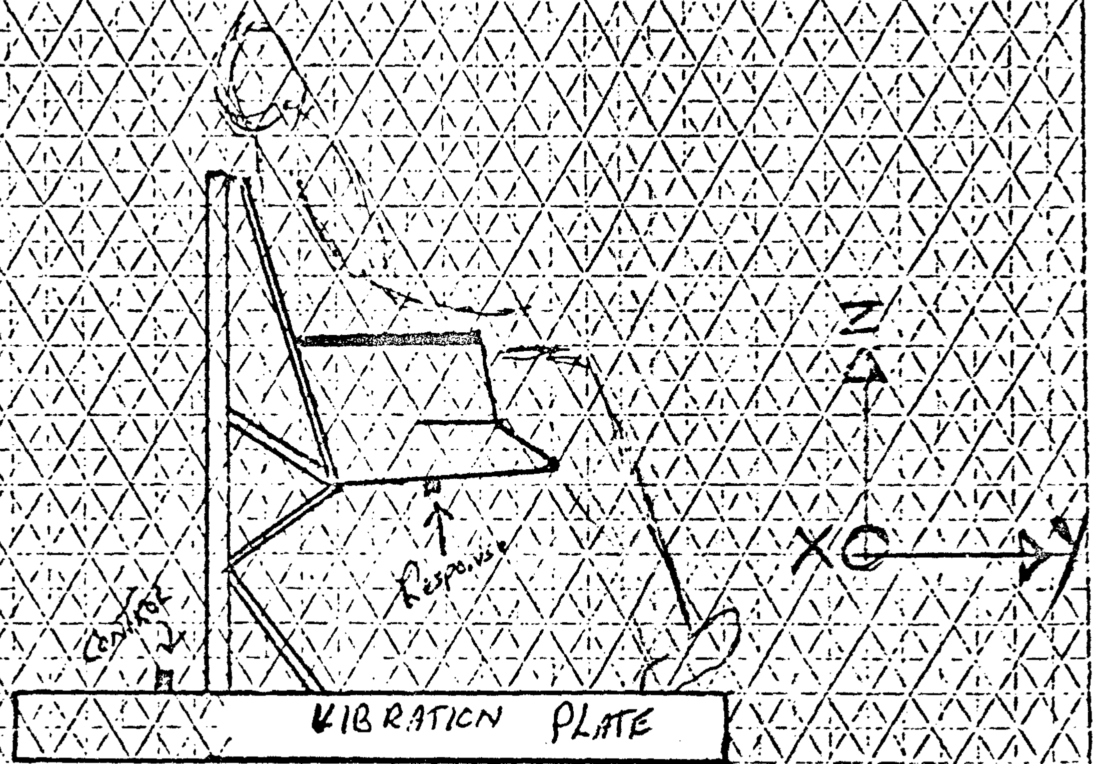
Quality Assurance Manager

TEST DATA - SINUSOIDAL VIBRATION

DATE STARTED	2-21-73
DATE COMPLETED	2-23-73
CUSTOMER	ACA INC.
SPECIMEN DESCRIPTION	Roll Assy & Set P/N D-2324 P/N D2269
TEST SPECIFICATION	MIL STD 810B Meth. 514 Proc. I
TECHNICIAN	D.W. Schuster
JOB NUMBER	F-72683

PHOTO TAKEN ☒ YES ☐ NO
DRAWING ATTACHED ☒ YES ☐ NO
DAMAGE INCURRED ☐ YES ☒ NO

DATE	TIME	TEMPERATURE	FREQUENCY	DISPLACEMENT	ACCELERATION	AXIS	SWEEP RATE	DURATION	TEST SEQUENCE	RESPONSE MONITOR	RESPONSE AMPLITUDE	RESPONSE FREQUENCY	SPECIMEN OPERATION / COMMENTS
1973	HOUR	°F	Hz	INCH D.A.	G/PK	X-Y-Z	OCT/MIN	MIN	NOTED	AXIS	G/PK	Hz	
2-21	1255		5-20	.1		Vert	.8	15	1				Resonance Search
			20-33		2.0								
			33-500		2.5								
			500-5	Same	Same								
	1325		29		2.0	Vert	-	30	2	Vert	4g	29	Dwell
	1355		34		2.5	Z	—	30	3	Z	5g	34	Dwell
	1425		50		2.5	Z	--	30	4	Z	5.5	50	Dwell 2 Rods on Back broke.
	1515		435		2.5	Z	—	30	5	Z	5.0	435	Dwell
	1545		Same as Seq #1			Z	—	45	6				Cycling
2-22	1018		Same as Seq #1			Y		15	7				Resonance Search
	1037		43		3.5	Y	-	30	8	Y	4.0	43	Dwell
	1108		Same as Seq #1			Y	-	135	9				Cycling One Rod broke on cycling
	1520		Same as Seq #1			X	-	15	10				Resonance Search
	1540		Same as Seq #1			X	—	30	11				Cycling (No Dwells)
2-23	0840		Same as Seq #1			X	-	135	12				Resume cycling


Z
X
Y
Response
Control
VIBRATION PLATE

OGDEN TECHNOLOGY CORP.

J/N F-72683 RUN NO. 1

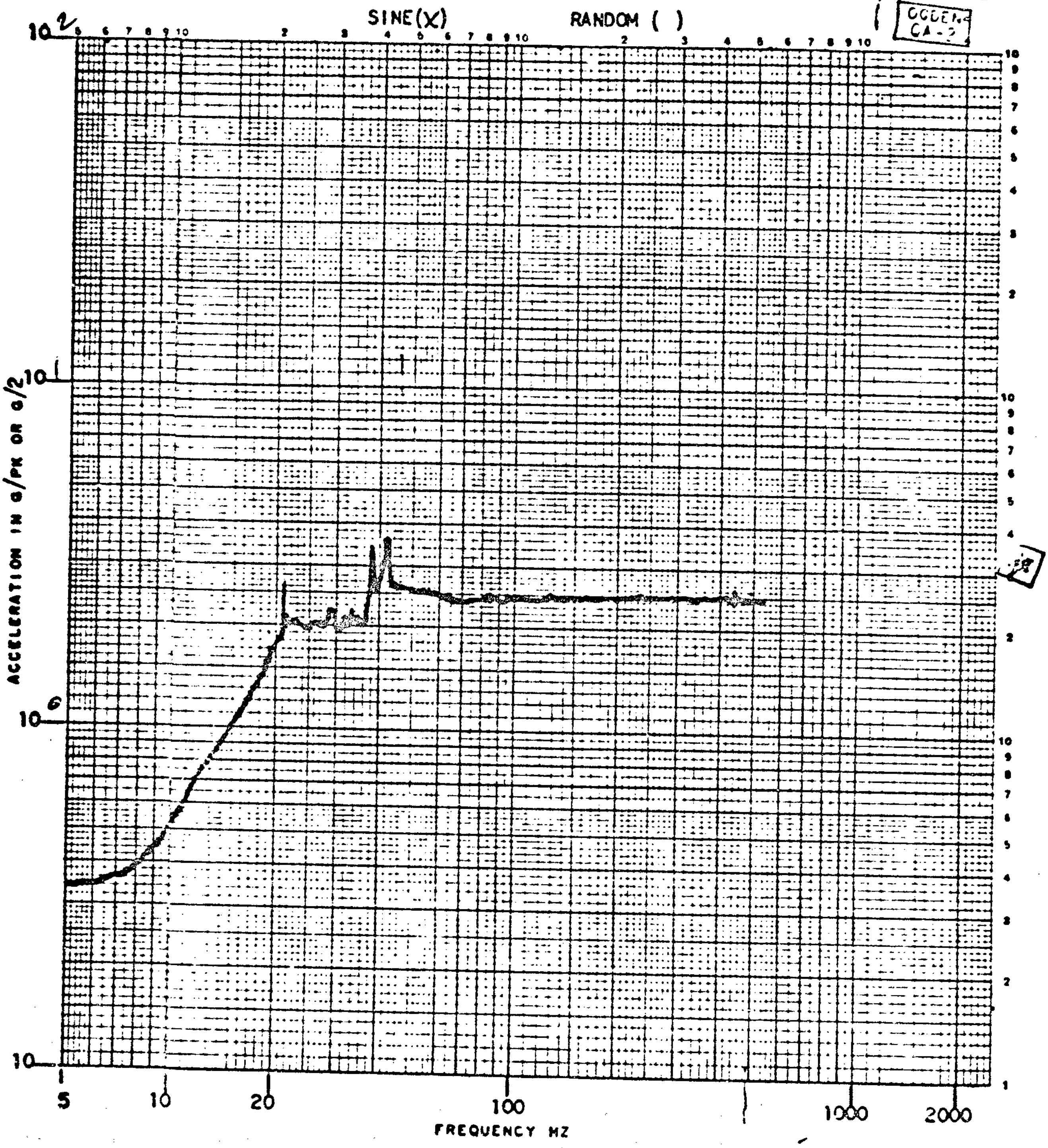
CUSTOMER ARA Inc. Helicopter Seat DATE 2-21 1973

SPECIMEN S/N ______, P/N D-2324, D2269

ACCEL NO 1, CONTROL (✓) RESPONSE ( )

TECHNICIAN ______, AXIS Vert, FULL SCALE 100, "G" RMS

SINE (X) RANDOM ( )



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OGDEN TECHNOLOGY CORP.

J/N F-72683 RUN NO. 1

CUSTOMER ARA INC Helicopter DATE 2-21 1973

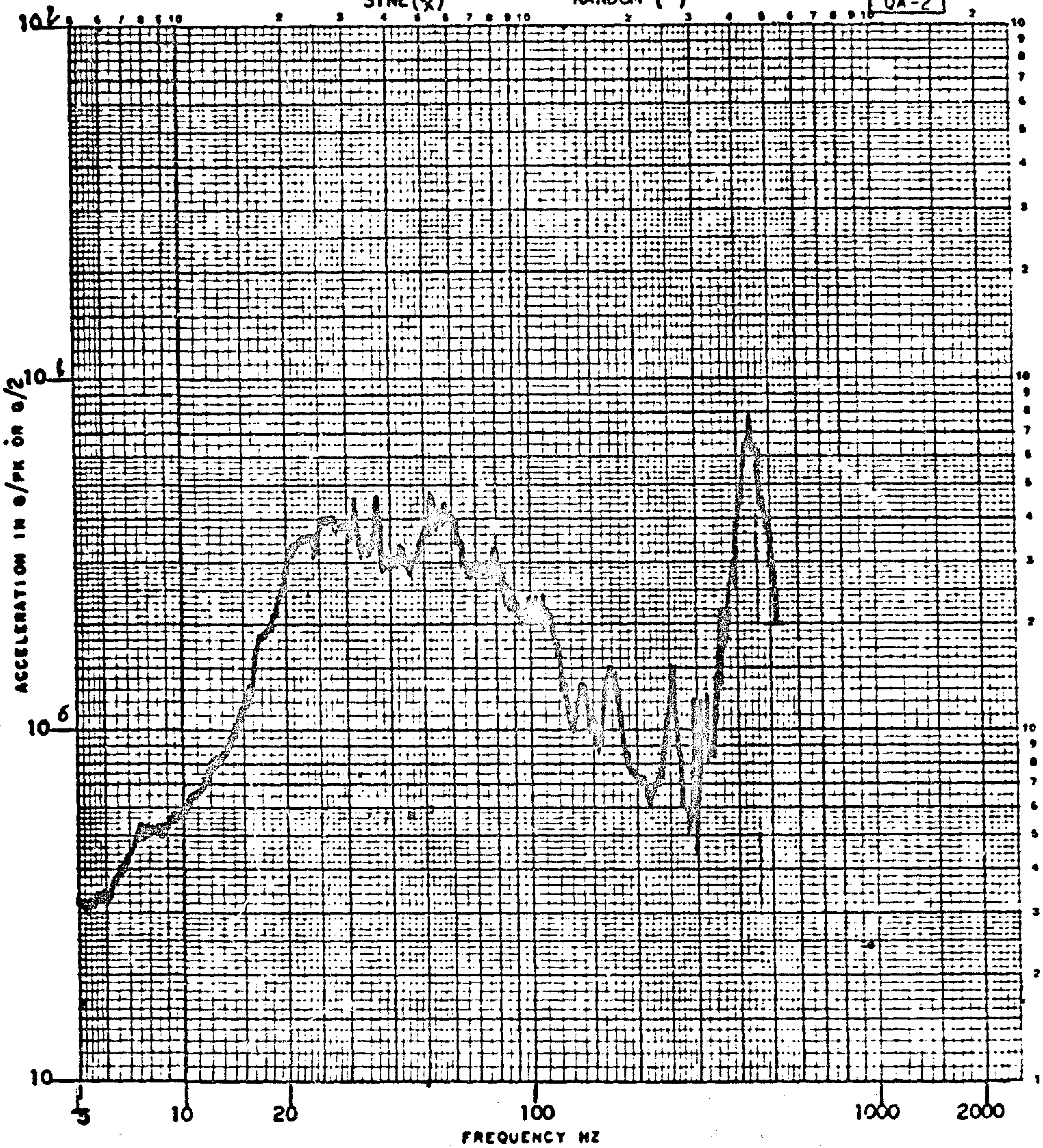
SPECIMEN S/N ____, P/N D 2324 D 2269

ACCEL NO 2, CONTROL ( ) RESPONSE (X) ON Bottom of Seat

TECHNICIAN ____, AXIS Vert, FULL SCALE 100, "G"RMS ____

SINE (X) RANDOM ( )

OGDEN OA-2



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OGDEN TECHNOLOGY CORP.

J/N F-72683 RUN NO. 6

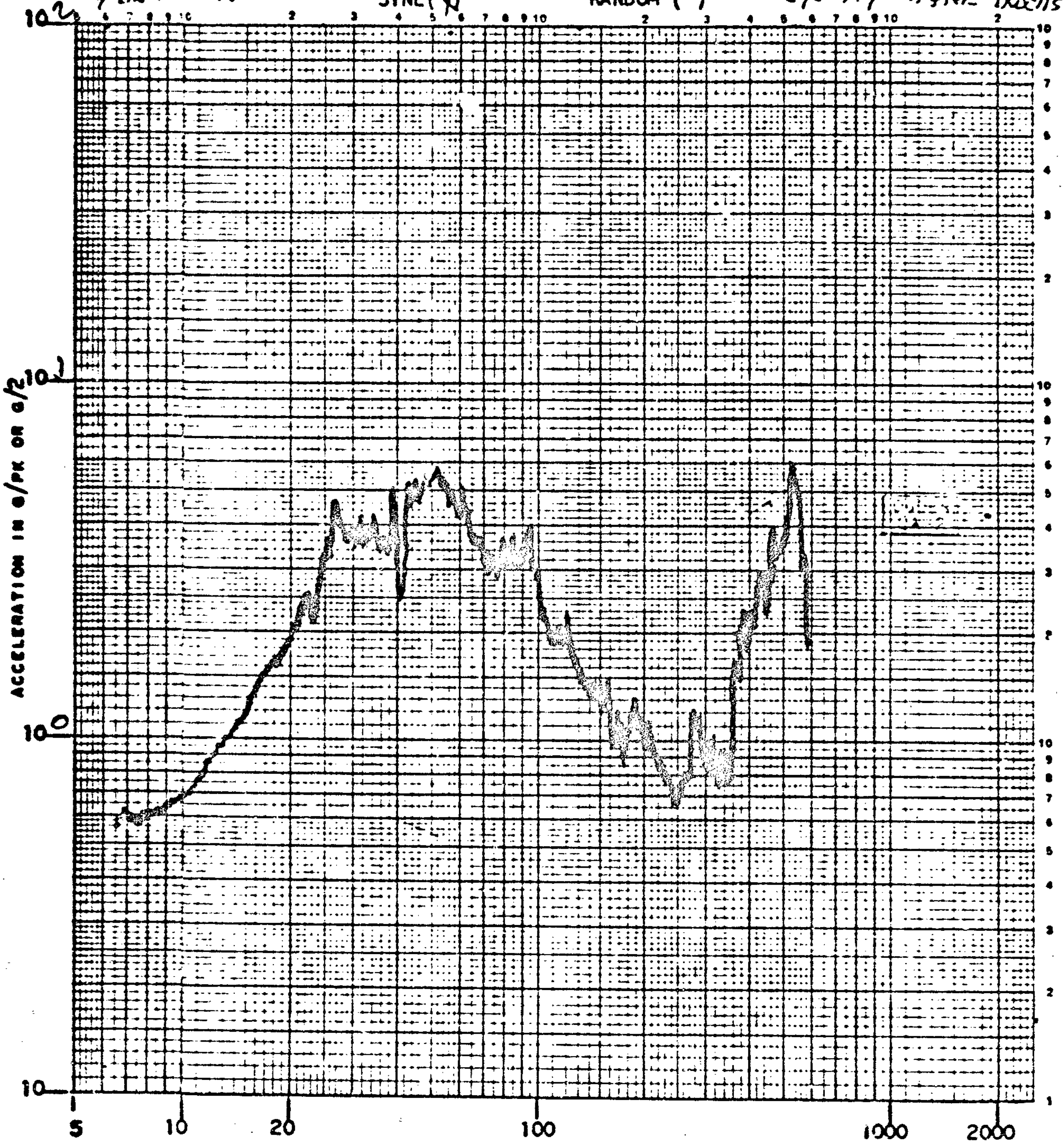
CUSTOMER ARA INC DATE 2-21 1973

SPECIMEN S/N ____________, P/N D2324 , D2269

ACCEL NO 2 , CONTROL ( ) RESPONSE (X)

TECHNICIAN [illegible] , AXIS Z , FULL SCALE 10G , "G"RMS ________

w/Broken Rods SINE(X) RANDOM ( ) Cycling After Dwells



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OGDEN TECHNOLOGY CORP.

J/N F-72683 RUN NO. 6

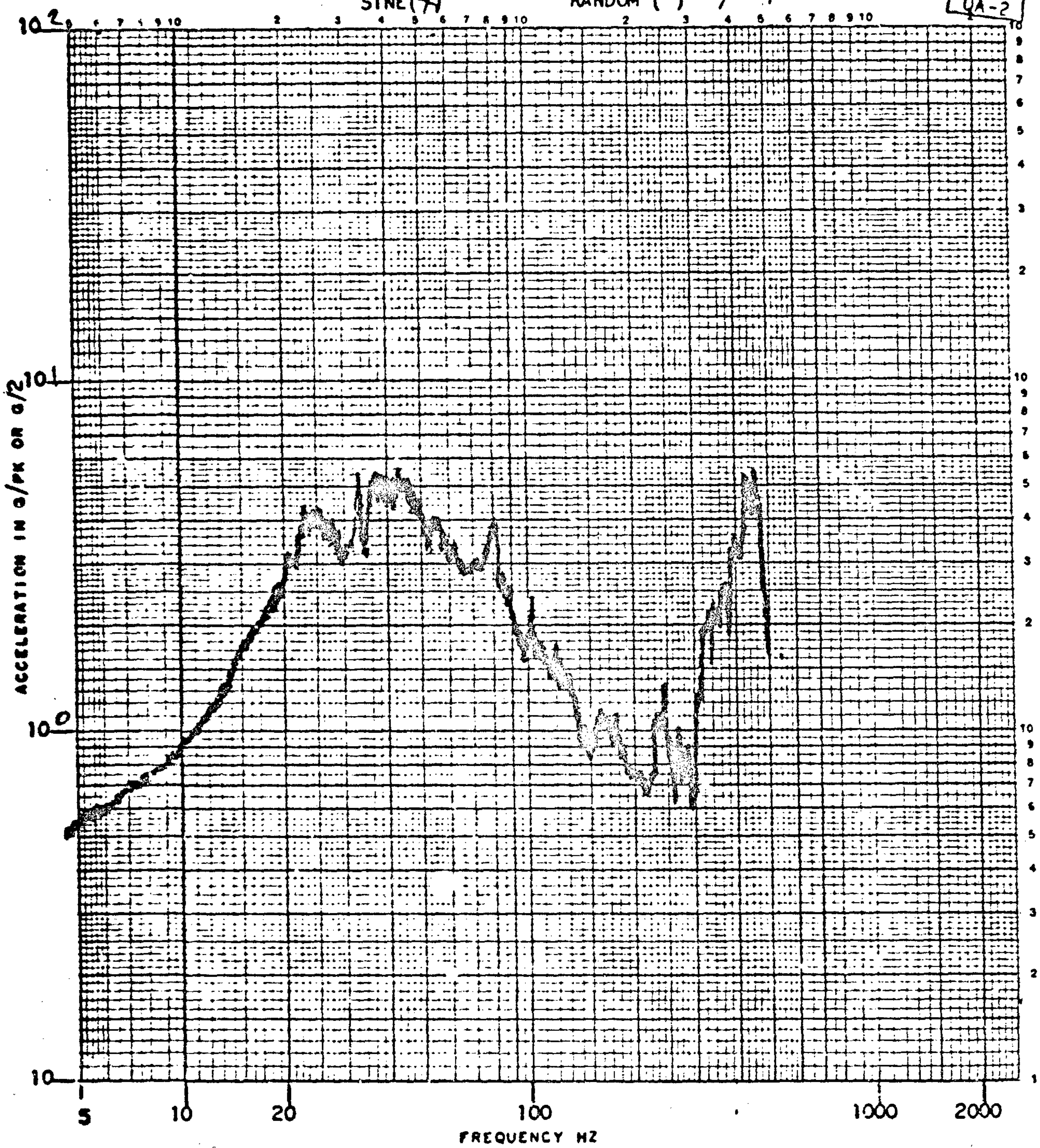
CUSTOMER ARA INC DATE 2-21 1973

SPECIMEN S/N ____, P/N D2324, D2269

ACCEL NO 2, CONTROL ( ) RESPONSE (X) ON Bottom of Seat

TECHNICIAN ____, AXIS Z, FULL SCALE 100 g, "G"RMS ____

SINE (X) RANDOM ( ) Cycling without Red. OGDEN QA-2



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OGDEN TECHNOLOGY CORP.

J/N F-72683 RUN NO. 6

CUSTOMER ARA Inc DATE 2-21 1973

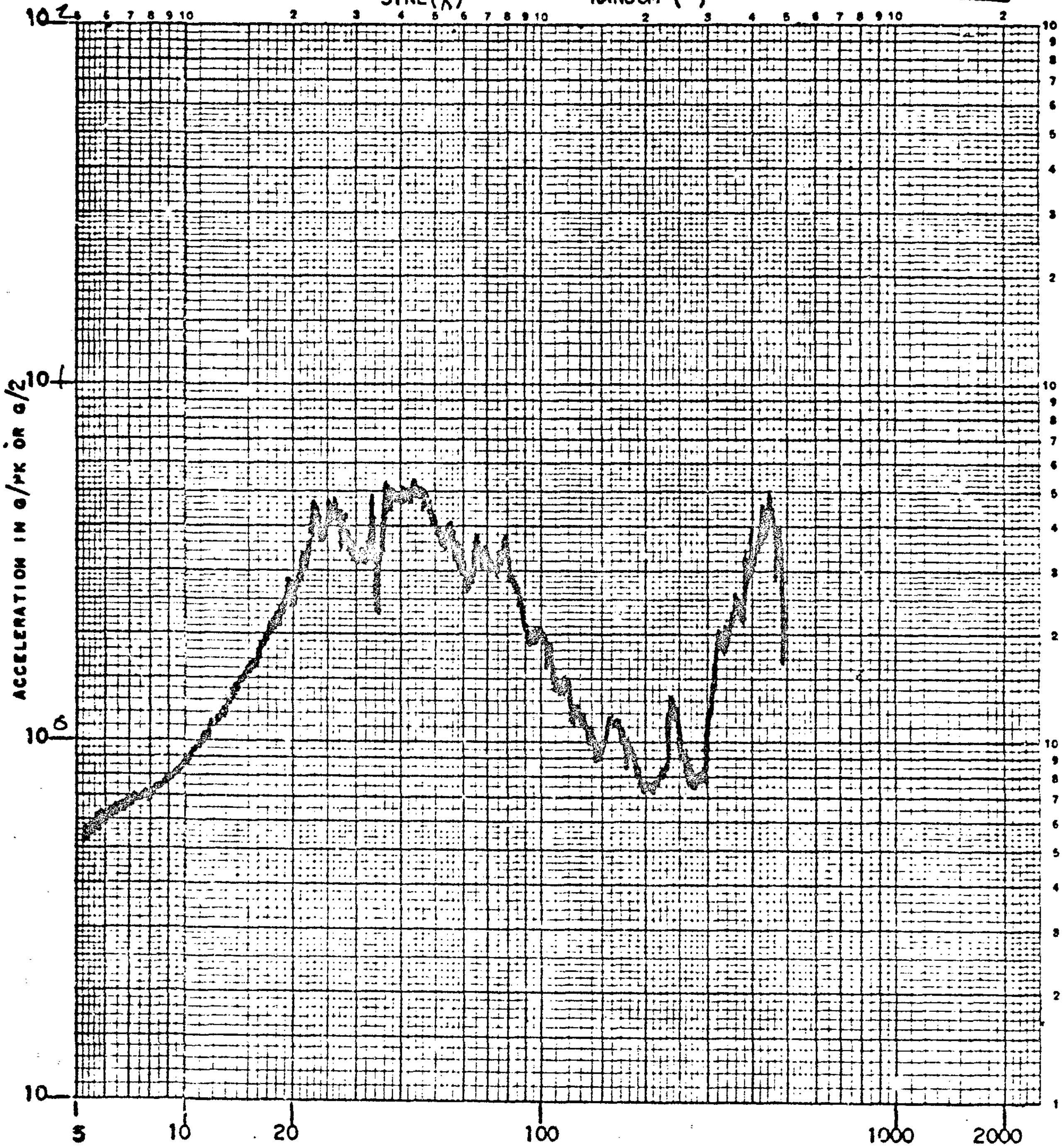
SPECIMEN S/N ______, P/N D2324, D2269

ACCEL NO 2, CONTROL ( ) RESPONSE (X) on Bottom of Seat

TECHNICIAN Deot, AXIS Z, FULL SCALE 100, "G"RMS

OGDEN QA-2

SINE(X) RANDOM ( )



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OGDEN TECHNOLOGY CORP.

J/N F-72683

RUN NO. 7

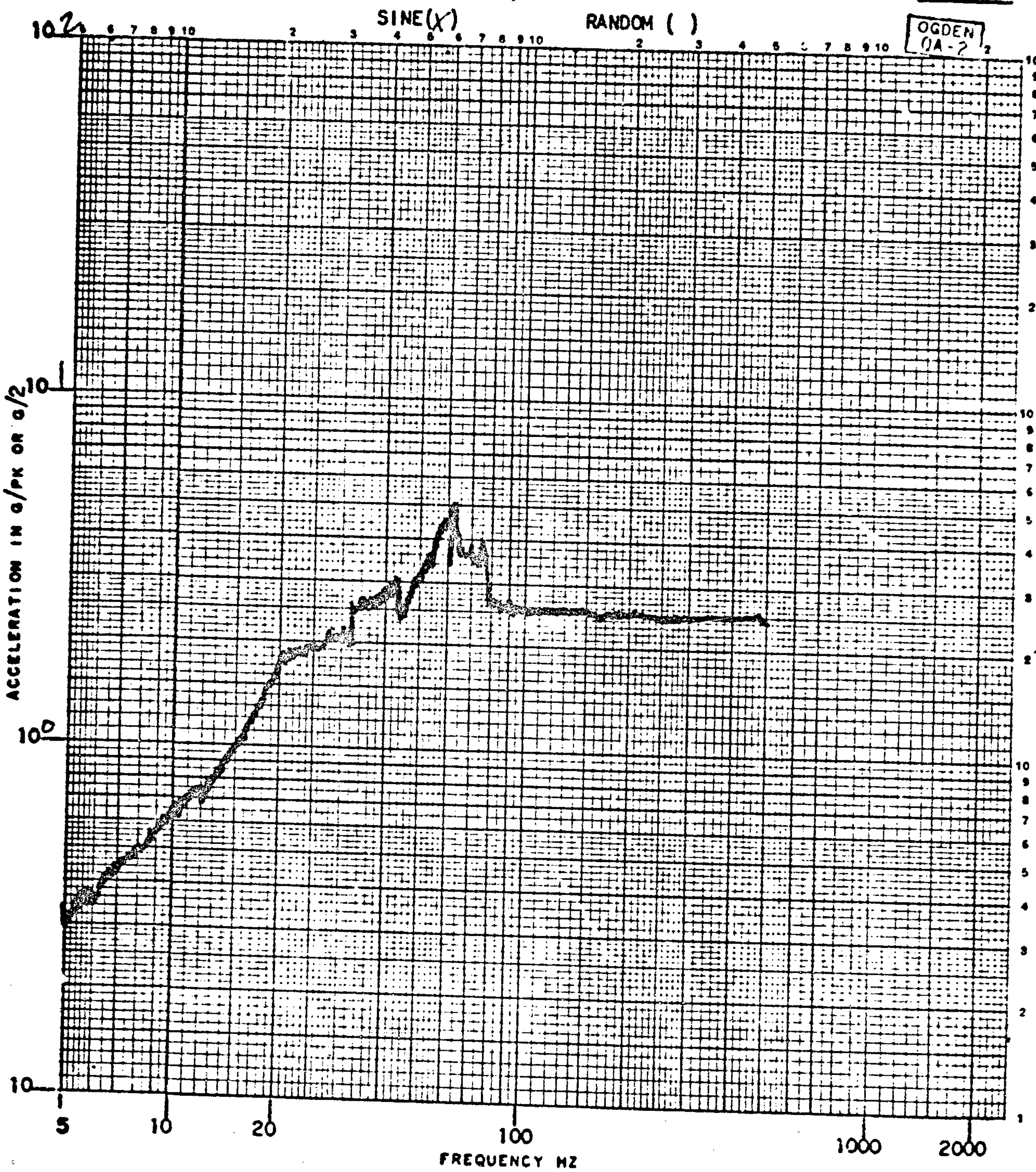
CUSTOMER ARA INC

DATE 2-22 1973

SPECIMEN S/N ______, P/N D-2324 D 2269

ACCEL NO. 2, CONTROL (X) RESPONSE ( )

TECHNICIAN ______, AXIS Y, FULL SCALE 100, "G"RMS ______



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REPORT NO. F-72683

OGDEN TECHNOLOGY CORP.

J/N F-72683 RUN NO. 7

CUSTOMER ARA INC. Helicopter Seat DATE 2-22 1973

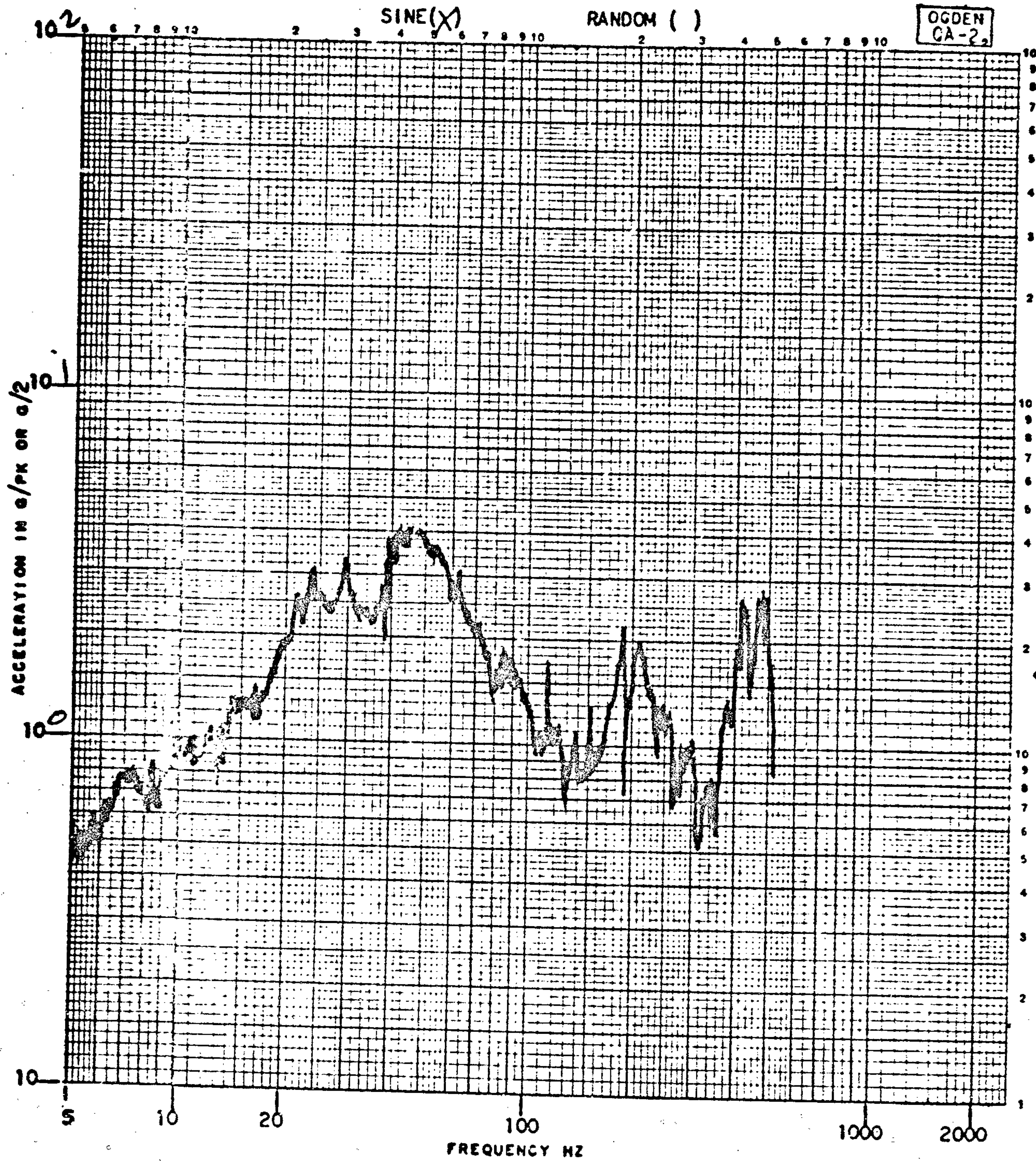
SPECIMEN S/N ______, P/N D-2324, D2269

ACCEL NO 2, CONTROL ( ) RESPONSE (X)

TECHNICIAN Aust, AXIS Y, FULL SCALE 100, "G"RMS ______

SINE(X) RANDOM ( )

OGDEN CA-2



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OGDEN TECHNOLOGY CORP.

J/N F-72683 RUN NO. 9

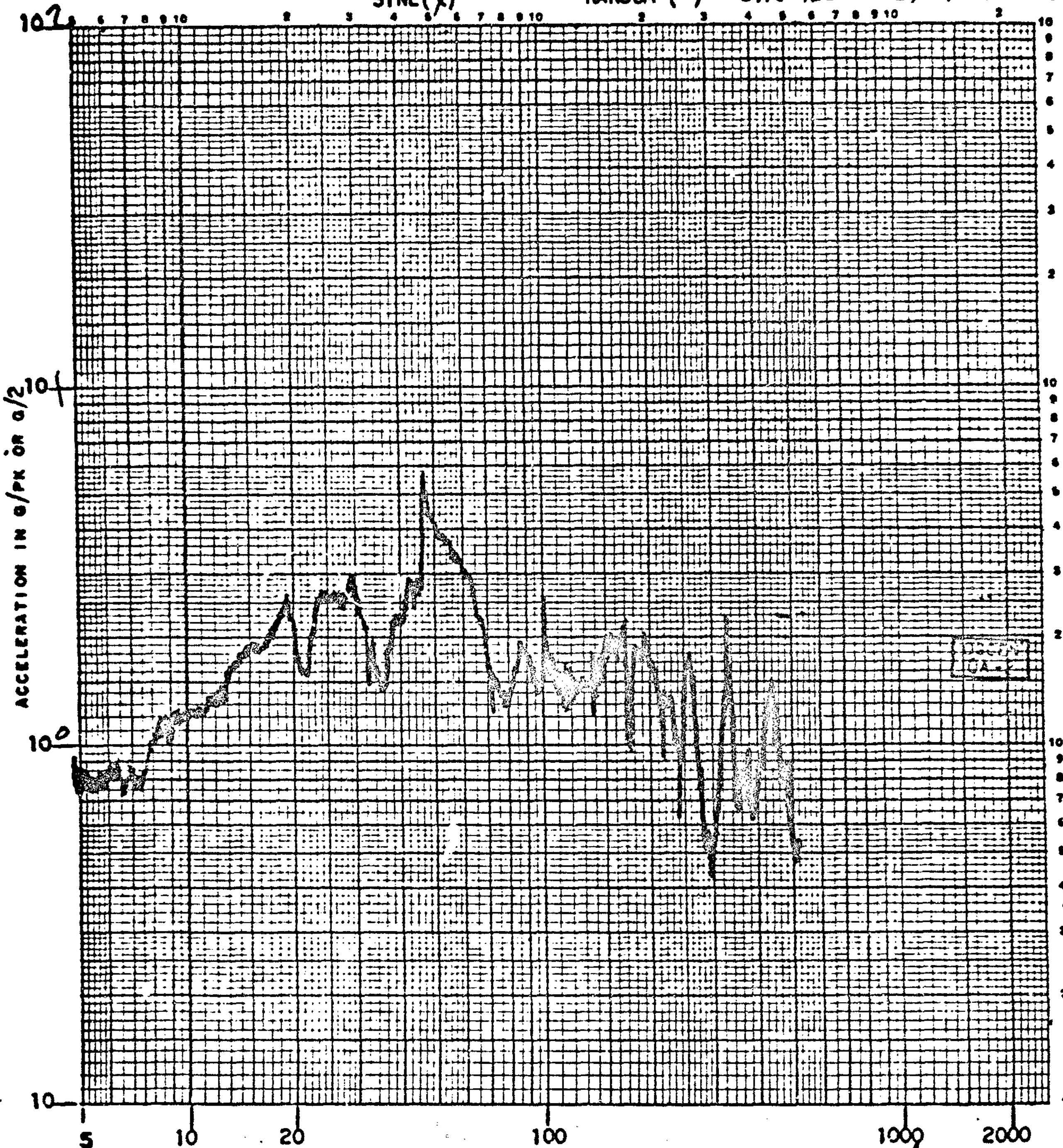
CUSTOMER ARA INC Helicopter Seat DATE 2-22 1973

SPECIMEN S/N ____, P/N D2324- D2269

ACCEL NO 2, CONTROL ( ) RESPONSE (X) ON BOTTOM OF SEAT

TECHNICIAN ____, AXIS Y, FULL SCALE 10G, "G"RMS ____

SINE(X) RANDOM ( ) ONE Rod ON BACK Broke



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OGDEN TECHNOLOGY CORP.

J/N F-72683 RUN NO. 10

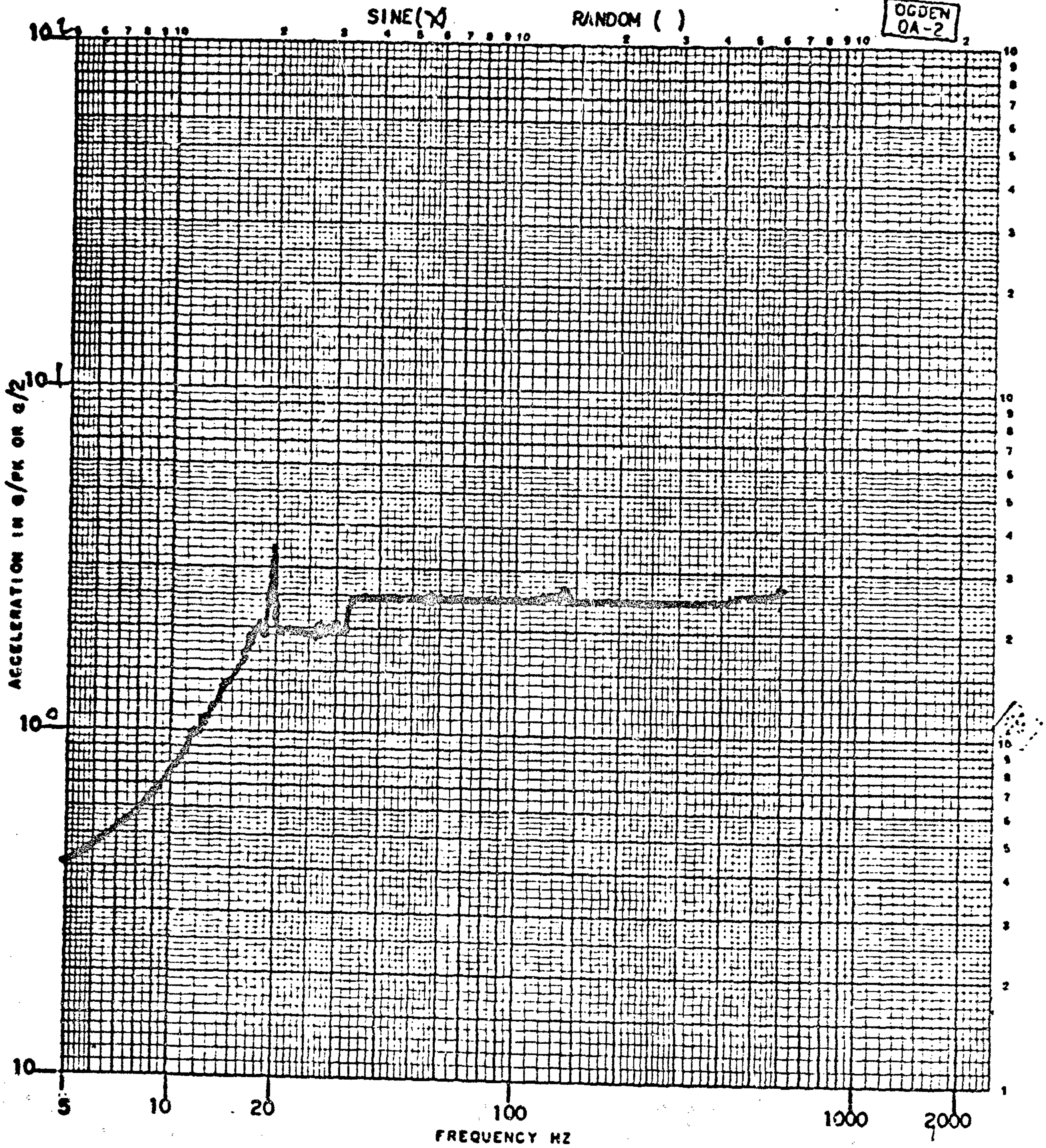
CUSTOMER ARA Inc Helicopter Seat DATE 2-22 1973

SPECIMEN S/N ______, P/N D2324, D2269

ACCEL NO. 1, CONTROL (X) RESPONSE ( )

TECHNICIAN [illegible], AXIS X, FULL SCALE 100, "G" RMS

SINE (X) RANDOM ( ) OGDEN OA-2



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OGDEN TECHNOLOGY CORP.

J/N F-72683 RUN NO. 10

CUSTOMER ARA INC HELICOPTER DATE 2-22 1973

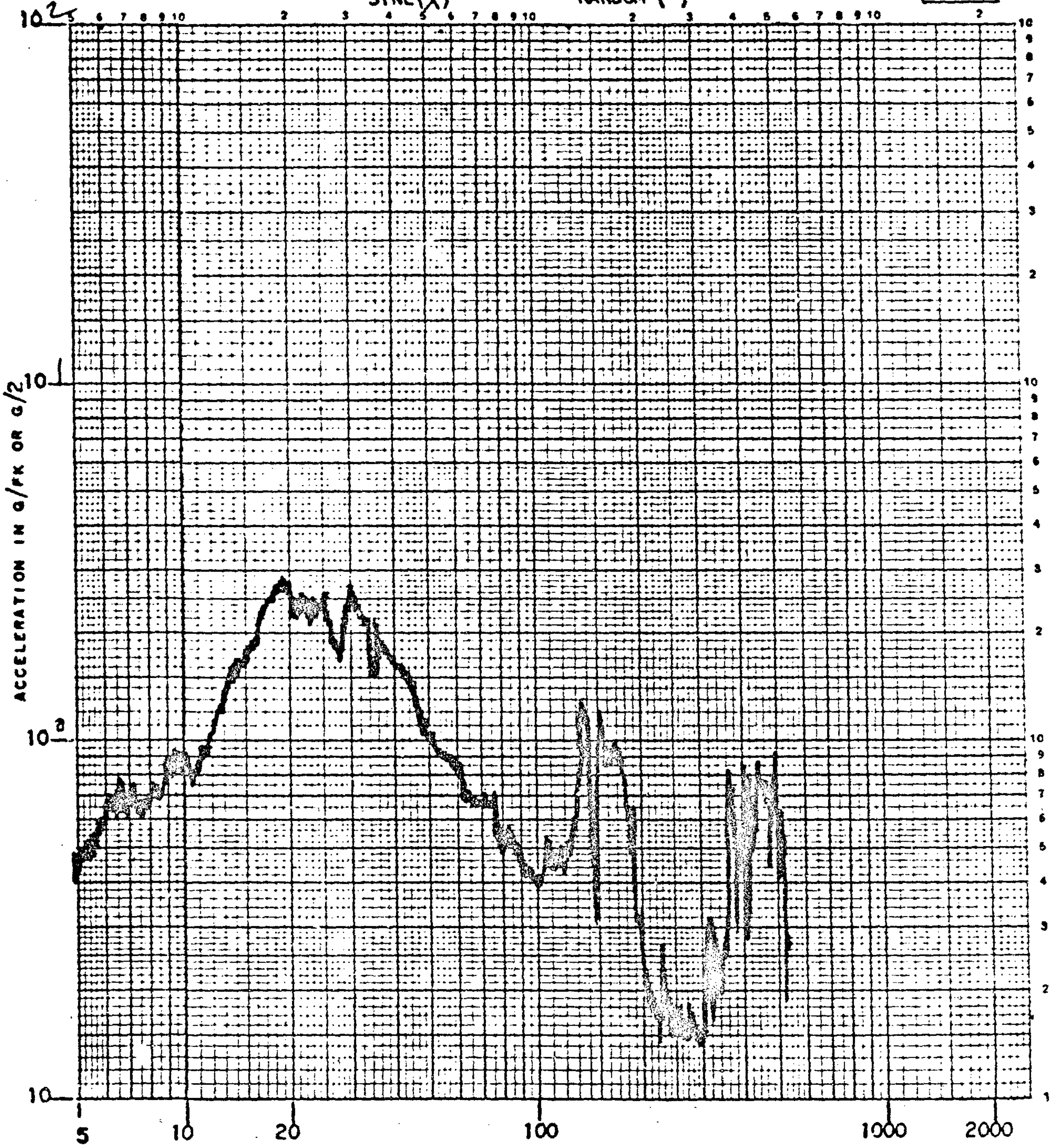
SPECIMEN S/N ______, P/N D-2324 D2269

ACCEL NO 2, CONTROL ( ) RESPONSE (X) ON BOTTOM OF SEAT

TECHNICIAN ______, AXIS X, FULL SCALE 100, "G"RMS

OGDEN QA-2

SINE(X) RANDOM ( )



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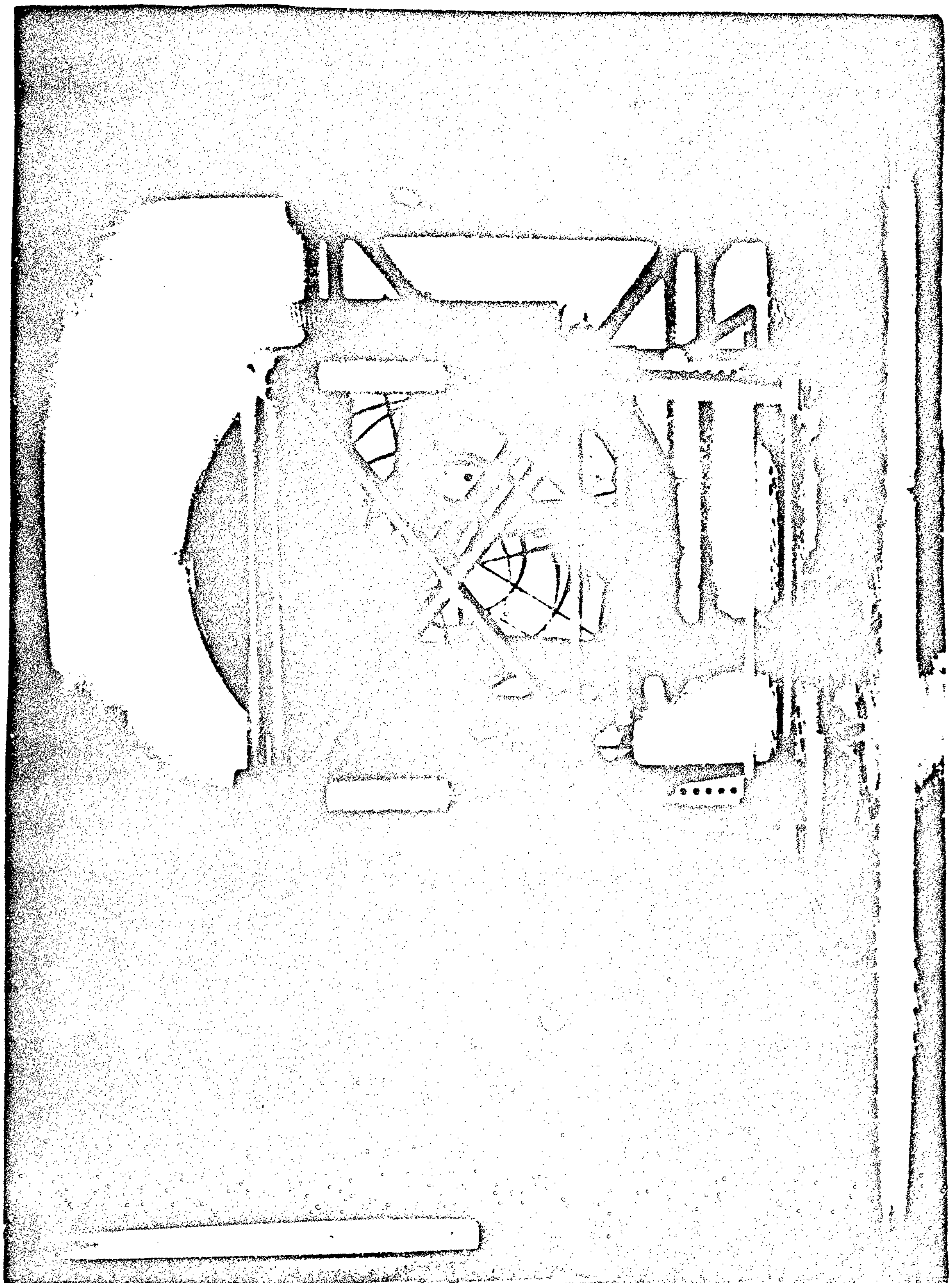
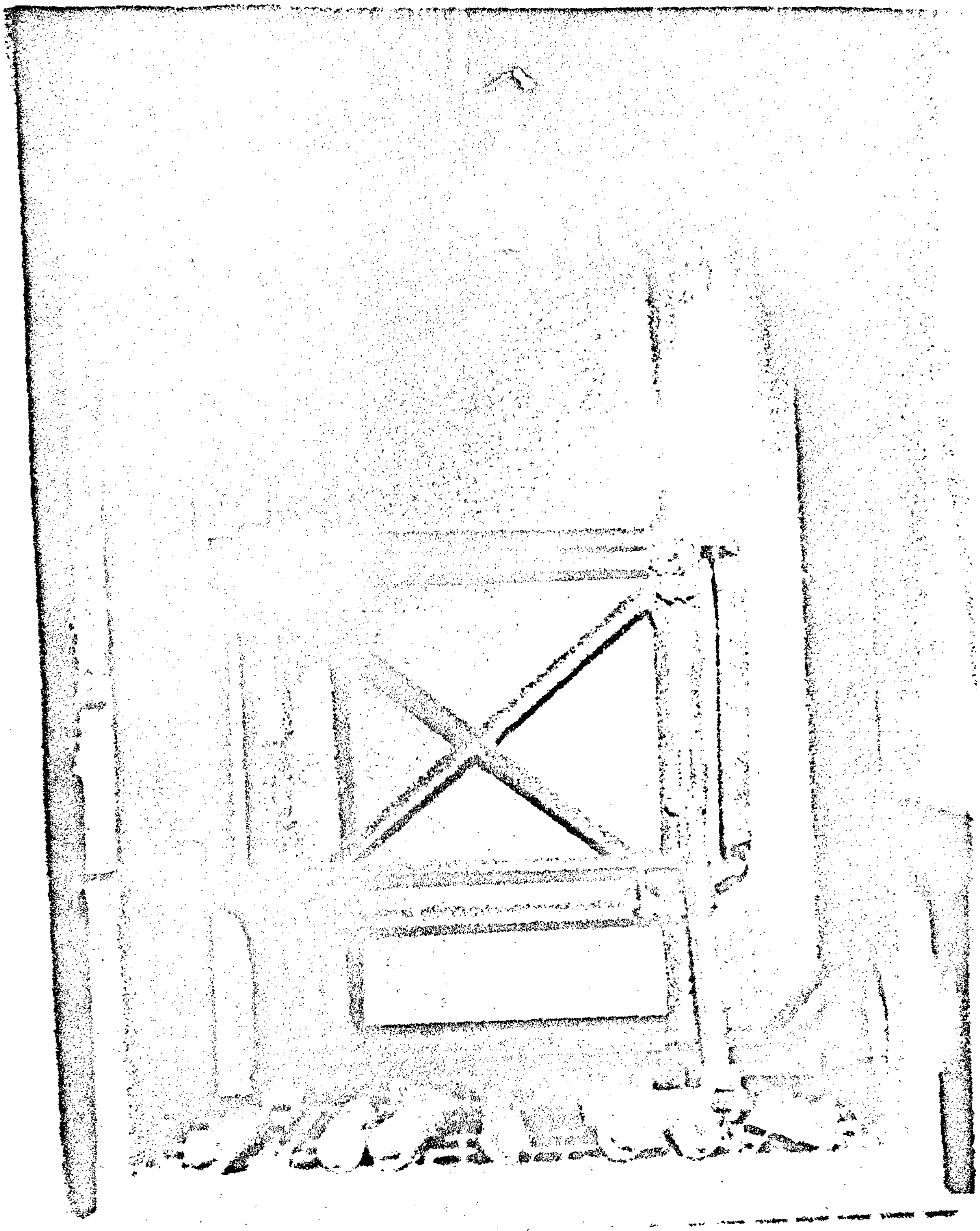


PHOTOGRAPH No. 1



PHOTOGRAPH No. 2

PHOTOGRAPH No. 3